US
H
8

Library

Arnold Arboretum

VE RI
TAS

of

Harvard University

Mass Society for
Promoting
Agriculture
with Prof Storer's compliments
April 18. 1876

HARVARD UNIVERSITY.

BULLETIN

OF THE

BUSSEY INSTITUTION

[JAMAICA PLAIN (BOSTON)].

VOL. I.

1874—1876.

CAMBRIDGE:
PRESS OF JOHN WILSON AND SON.

ARNOLD
ARBORETUM

45696
Oct 20, 1944

Given by Univ. of Kansas Library

TABLE OF CONTENTS.

BULLETIN

OF

THE BUSSEY INSTITUTION.

HARVARD UNIVERSITY, 15th November, 1873.

THE experiments and investigations made at the Bussey Institution will be published from time to time in a "Bulletin."

It seemed fitting that the first number of the Bulletin should contain some account of the origin, objects, and resources of the Institution.

THE Bussey Institution is a School of Agriculture and Horticulture, established as a department of Harvard University under the trusts created by the will of Benjamin Bussey of Roxbury, Massachusetts, bearing date July 30, 1835.

Mr. Bussey's will was proved and allowed on the first Tuesday of March, 1842. It conveyed his estate, real and personal, to seven trustees, who were required to pay legacies amounting to about nineteen thousand dollars, and annuities amounting to about twelve thousand dollars a year; to give to the widow the occupation of an estate in Boston for her life; to give to the widow, to Francis C. Head, Esq., and to his granddaughter, Mrs. Thomas Motley, in succession, the occupation for life of his estate in West Roxbury called Woodland Hill; and finally, after these

life-estates had expired and all the legacies and annuities had been paid or secured, to convey all the testator's property, real, personal, and mixed, to the President and Fellows of Harvard College upon the conditions and for the purposes set forth in the following extracts from the will: —

"Before proceeding to make a further disposition of my property and estate, I think it will tend to elucidate and explain the several devises and dispositions thereof, hereinafter made, to state that in making this will I have two objects chiefly in view. My primary object has been to provide in the best and most secure manner in my power a comfortable and respectable living after my decease for my family, namely, my wife, if she shall outlive me, and my daughter and her children now living, and to make some provision for great-grandchildren. My second object has been to benefit my fellow-citizens and posterity, according to my ability, by devoting ultimately a large portion of my fortune to promote those branches of education which I deem most important and best calculated to advance the prosperity and happiness of our common country. I have also felt a particular desire to increase the usefulness of the schools of Law and Theology at Harvard College in Cambridge. In a nation whose government is held to be a government of laws, I deem it important to promote that branch of education which lies at the foundation of wise legislation, and which tends to insure a pure and uniform administration of justice; and I have considered that, in a country whose laws extend equal protection to all religious opinions, that education which tends to disseminate just and rational views on religious subjects is entitled to special patronage and support. . . . .

"And I do hereby further declare that all the real and personal property and estate so conveyed, transferred, and delivered to the President and Fellows of Harvard College shall stand charged and chargeable with the said annuities and payments, if not paid or provided for, and shall be taken and held by said President and Fellows of Harvard College as a permanent, public corporate body specially charged with the care and superintendence of the higher branches of education, *upon the trust and confidence* that they will manage and invest the same to the best advantage; that they will retain the estate on which I now live in said Roxbury, called 'Woodland Hill,' consist-

ing of over two hundred acres of land, as a place in my judgment well adapted, from the great variety and excellence of its soil, its hills, valleys, and water, its great diversity of surface and exposure, and lastly, its high state of cultivation and improvement, for all the objects contemplated. That they will establish there a course of instruction in practical agriculture, in useful and ornamental gardening, in botany, and in such other branches of natural science as may tend to promote a knowledge of practical agriculture and the various arts subservient thereto and connected therewith, and cause such courses of lectures to be delivered there at such seasons of the year and under such regulations as they may think best adapted to promote the ends designed; and also to furnish gratuitous aid, if they shall think it expedient, to such meritorious persons as may resort there for instruction: the institution so established shall be called the 'Bussey Institution.'. . . .

"And it is my will that one half of the net income of all my estates and property so conveyed to said President and Fellows of Harvard College shall be appropriated to the support of said institution, and of such branches of instruction in the physical sciences, there or at Harvard College, as are subservient thereto, and connected with the great objects of said institution; and it is my will that the other half of the net income of said estates and property so conveyed to said President and Fellows of Harvard College shall be annually appropriated, one half thereof to the encouragement and promotion of theological education, and the other moiety to the encouragement and promotion of legal education in said College, by the endowment of professorships or scholarships in the Theological and Law Schools respectively; by the purchase of books, erection of buildings, and by such other means as may in their judgment render the income of the property hereby appropriated most available in the accomplishment of the objects proposed. . . . .

"And being desirous that every proper accommodation should be secured for the officers and pupils of said institution, I hereby order and direct my trustees, as soon as they shall deem it expedient and consistent with the state of the trust funds, to cause to be erected on the 'Plain-field,' so called, next easterly of my farm garden, and bounded southeasterly on the road running from said 'Woodland Hill' to Boston, an edifice, with convenient outbuildings, suitable in all respects for said institution: the said edifice to be not less than

ten rods from said road; the exterior walls thereof to be built of stone in blocks (not hammered), or to be similar to the front wall of the 'Masonic Temple,' so called, in said Boston. And I earnestly enjoin it upon my trustees to have the said edifice constructed and completed with a proper regard to durability and beauty, and so as best to secure the comfort and convenience of the inmates of said building."

The will further provided that in case the President and Fellows of Harvard College, after the decease of Mrs. Bussey, should take upon themselves the payment of the annuities and other sums given by the will and the performance of all the other trusts enjoined upon the trustees, it should be the duty of the trustees immediately to pay over, transfer, and convey to the said President and Fellows all the trust estates, real and personal, remaining in their hands.

Under this provision, in May, 1861, the trustees transferred all the property in their possession to the President and Fellows at a valuation of $413,290.69, exclusive of the Woodland Hill estate. At the time of this transfer the amount of the annuities was $9,300, the income of the whole property was $32,130, and the Woodland Hill estate was occupied by Mrs. Thomas Motley. The President and Fellows immediately applied one quarter of the net income of the property to the uses of the Divinity School, and another quarter to the uses of the Law School, and directed that the remaining half should be carried year by year to a fund which should accumulate at compound interest. This fund they proposed to use for building purposes whenever it should become their duty to organize and equip the "Bussey Institution."

Nine years later, in the spring of 1870, the President and Fellows began the organization of the school of agriculture and horticulture which Mr. Bussey had planned and provided for thirty-five years before. The income of the property had risen to $38,187, the annuities had fallen to $7,100, and the accumulating fund for purposes of building and equipment had reached $75,076.94. Mrs. Motley still occupied the estate at West Rox-

bury, called Woodland Hill; but for certain considerations, which were satisfactory to her, she relinquished her life-estate in a field of about seven acres, called the Plain-field, which was designated by Mr. Bussey as the site of the building for the Bussey Institution. The indentures which contain this agreement bear date July 1 and September 5, 1870. Simultaneously (July 8, 1870) the trustees of the Massachusetts Society for Promoting Agriculture, desiring to aid in building up an establishment for carrying on agricultural experiments and investigations and diffusing a knowledge of sound agricultural principles and methods, granted to the President and Fellows of Harvard College $ 3,000 "for the support of a laboratory, and for experiments in agricultural chemistry to be conducted on the Bussey estate," and, in view of the time needed for agricultural inquiries, passed a resolution that, "in the opinion of the trustees of this society, the annual sum of $ 3,000 should be continued for a term of not less than five years." Accordingly, in each succeeding year, the trustees of the society have given $ 3,000 to the President and Fellows; but one half of the second grant was used, at the request of the trustees, for the department of horticulture at the Bussey Institution, and one half of the third for the Botanic Garden at Cambridge. Since September 1, 1870, the President and Fellows have erected upon the Plain-field, in accordance with the directions given in Mr. Bussey's will, a handsome stone building, containing a lecture-room, a laboratory with suitable store-rooms and a glass-house in connection therewith, a library-room, an office, three recitation-rooms, some chambers, and several large rooms to receive illustrative collections. The grounds and avenues have been prepared, glass-houses, sheds, and hot-beds for the department of horticulture have been built and stocked, and a permanent water-supply for the whole estate has been contrived and constructed. On September 1, 1873, there remained of the fund accumulated for purposes of building and equipment, $ 21,544.93. The laboratory was not equipped and ready for occupation until the last week of 1871, since which date agricultural researches have been steadily pros-

ecuted by the professor of agricultural chemistry and his assistants. The library has been begun, and some progress has been made towards gathering collections in applied zoölogy and entomology. The appointments thus far made in the Institution are as follows: —

An Instructor in Farming (October 12, 1870).
A Professor of Agricultural Chemistry (November 25, 1870).
A Professor of Horticulture (March 8, 1871).
A Professor of Applied Zoölogy (March 8, 1871).
An Instructor in Entomology (March 31, 1871).
A Director of the Arnold Arboretum (June 19, 1872).
A Librarian and Curator of Collections (November 10, 1873).

The President and Fellows will be glad to have the opportunities and facilities provided by the Bussey Institution recognized and utilized by the public, and to see students resorting thither for instruction in the arts and sciences which subserve agriculture and horticulture; but students' fees are not necessary to the support of the Institution. The permanent funds provided by Mr. Bussey will enable the President and Fellows to maintain the Institution as a scientific station, like the Astronomical Observatory or the Museum of Comparative Zoölogy at Harvard College, until the time shall come when there shall be a demand for its privileges as a school.

In the spring of 1872 the President and Fellows received a gift of $100,000 from the trustees under the will of the late James Arnold, merchant, of New Bedford, Massachusetts, for the purpose of establishing in the Bussey Institution a professorship of tree-culture, and creating and maintaining on the Bussey estate an arboretum which shall ultimately contain, as far as is practicable, all the trees, shrubs, and herbaceous plants, either indigenous or exotic, which can be raised in the open air at West Roxbury. At least two thirds of the income of the fund is to be accumulated until the fund amounts to at least $ 150,000, and the Bussey estate (Woodland Hill) in West Roxbury passes completely into the hands of the President and Fellows. A particular portion of the estate has been specified as the site of the arboretum in the

indenture which defines the objects and terms of this gift, — a portion which contains about one hundred and thirty-seven acres, and is the finest part of the whole estate as regards the variety of its soils, the beauty and variety of the trees already growing upon it, and the lay of the land. An arboretum is intended to educate the public, as well as the special students who resort to it. When Woodland Hill comes into the possession of the President and Fellows, the Arnold Arboretum will doubtless be laid out as an open park, with suitable walks and roadways. It can hardly fail to become a beautiful, wholesome, and instructive resort, which will be more and more precious as population grows denser about it.

No. 1. — *A Report of Results obtained on examining some Commercial Fertilizers, by way of Analysis,** by F. H. STORER, Professor of Agricultural Chemistry in Harvard University.

A SET of field experiments undertaken at the Bussey Institution in behalf of the trustees of the Massachusetts Society for Promoting Agriculture, for the purpose of testing the efficacy of a variety of materials procurable in Boston and supposed to possess fertilizing power, naturally led to the analysis of a considerable number of commercial manures, as set forth in the following pages.

The analyses in question were incidental to the field work, and wholly subordinate to it. They have little interest in themselves, except in so far as they go to confirm the fact already well known to chemists and to many farmers, that the fertilizers on sale in this vicinity are, as a general rule, of very poor quality, and to enforce anew the lesson that measures of reform in the matter of buying and selling manures are imperatively needed.

As will be seen on inspecting the following list, the substances examined were, with few exceptions, by no means worth the prices asked for them.

SUPERPHOSPHATES.

I. Wilson's Superphosphate, bought April, 1871, of J. Breck and Son, Boston.

Moisture expelled at 212°	11.12%	
Volatile matter (beside moisture)	23.58	
Ash left on ignition	65.30	
		100.00

* The manuscript of this article was presented in November, 1872, to the trustees of the Massachusetts Society for Promoting Agriculture, as a partial report of progress to the society, at whose expense the analyses had been made, and also as an appeal to the trustees to take action which might lead to an improvement in the quality and trustworthiness of a certain class of fertilizers in the New England market.

It will be observed that the paper is one of merely local interest. Wherever an experimental agricultural station has been established, one of the first questions

Of matters valuable as manure the specimen contained:—

Phosphoric acid soluble in water . .	4.81%	
" " insoluble "	7.86	
" " Total		12.67%

Total nitrogen, 1.25% =	ammonia, 0.18%, i. e. nitrogen	0.15%	
	nitrogen not in form of ammonia	1.10	
			1.25%

There was sand, &c., insoluble in acid, to the amount of . . . 3.54%

II. Wilson's Superphosphate, bought March, 1872, of J. Breck and Son, Boston.

Moisture	7.72	
Volatile matter (beside moisture) .	27.21	
Ash	65.07	
		100.00

Of matters valuable as manure the specimen contained:—

Soluble phosphoric acid	3.75%	
Insoluble " "	7.60	
Total " "		11.35%

Total nitrogen, 0.69% =	ammonia, 0.33%, i. e. nitrogen	0.28%	
	nitrogen not in form of ammonia	0.41	
			0.69%

There was sand, &c., to the amount of 2.31%

III. Coe's Superphosphate, bought April, 1871, of William L. Bradley, Boston.

Moisture	6.78%	
Volatile matter (beside moisture) .	35.14	
Ash	58.08	
		100.00

Of matters valuable as manure the specimen contained:—

Soluble phosphoric acid	4.49%	
Insoluble " "	10.49	
Total " "		14.98%

which presents itself for solution is that relating to the character of the fertilizers of the locality. The laboratory of the Bussey Institution has in its turn been forced to give some attention to this matter of detail.

As now printed, the paper retains its original form. It has been altered only by the incorporation of a few determinations made since the presentation of the report, and some slight additions explanatory of the estimates of values.

Total nitrogen, 2.02% =	ammonia, 0.75%, i. e. nitrogen	0.62%	
	nitrogen not in form of ammonia	1.40	
			2.02%
There was sand, &c., to the amount of			6.95%

IV. Coe's Superphosphate, bought March, 1872, of William L. Bradley, Boston.

Moisture	6.27%	
Volatile matter (beside moisture)	41.86	
Ash	51.87	
		100.00

Of matters valuable as manure the specimen contained:—

Soluble phosphoric acid	10.23	
Insoluble " "	1.82	
Total " "		12.05%

Total nitrogen, 1.92% =	ammonia, 0.52%, i. e. nitrogen	0.43%	
	nitrogen not in form of ammonia	1.49	
			1.92%
There was sand, &c., to the amount of			4.00%

V. "XL" Superphosphate, bought May, 1871, of William L. Bradley, Boston.

Moisture	7.53%	
Volatile matter (beside moisture)	36.87	
Ash	55.60	
		100.00

Of matters valuable as manure the specimen contained:—

Soluble phosphoric acid	5.67%	
Insoluble " "	10.26	
Total " "		15.93%

Total nitrogen, 2.71% =	ammonia, 0.96%, i. e. nitrogen	0.79%	
	nitrogen not in form of ammonia	1.92	
			2.71%
There was sand, &c., to the amount of			6.06%

VI. "XL" Superphosphate, bought March, 1872, of William L. Bradley, Boston.

Moisture	18.55%	
Volatile matter (beside moisture)	34.38	
Ash	47.07	
		100.00

Of matters valuable as manure the specimen contained: —

Soluble phosphoric acid	6.55%	
Insoluble " "	5.96	
Total " "		12.51%

Total nitrogen, 2.19% = { ammonia, 0.80%, i. e. nitrogen 0.66%; nitrogen not in form of ammonia 1.53 } 2.19%

There was sand, &c., to the amount of 3.29%

VII. Bay State Superphosphate, bought April, 1871, of J. Breck and Son, Boston.

Moisture	10.08%	
Volatile matter (beside moisture) .	41.38	
Ash	48.54	
		100.00

Of matters valuable as manure the specimen contained: —

Soluble phosphoric acid	10.23%	
Insoluble " "	3.57	
Total " "		13.80%

Total nitrogen, 1.40 = { ammonia, 0.62%, i. e. nitrogen 0.51%; nitrogen not in form of ammonia 0.89 } 1.40%

There was sand, &c., to the amount of 1.56%

VIII. Fales's Superphosphate, obtained June, 1872, from Whittemore, Belcher, & Co., Boston.

Moisture	6.04%	
Volatile matter (beside moisture) .	17.04	
Ash	76.92	
		100.00

Of matters valuable as manure the specimen contained: —

Soluble phosphoric acid	1.46%	
Insoluble " "	8.69	
Total " "		10.15%

Total nitrogen, 1.67% = { ammonia, 0.25%, i. e. nitrogen 0.21%; nitrogen not in form of ammonia 1.46 } 1.67%

There was sand, &c., to the amount of 29.63

IX. Russell Coe's Superphosphate, obtained April, 1872, by John R. Brewer, Esq., of Hingham.

Moisture	31.80%	
Volatile matter (beside moisture) .	27.26	
Ash	40.94	
		100.00

Of matters valuable as manure the specimen contained : —

Soluble phosphoric acid	7.68%	
Insoluble " "	4.18	
Total " "		11.86%
Total nitrogen, 0.95% = ammonia, 0.44%, i. e. nitrogen	0.36%	
nitrogen not in form of ammonia	0.59	
		0.95%
There was sand, &c., to the amount of		1.12%

X. Russell Coe's Superphosphate, obtained June, 1872, from Whittemore, Belcher, & Co., Boston.

Moisture	14.91%	
Volatile matter (beside moisture) .	32.33	
Ash	52.76	
		100.00

Of matters valuable as manure the specimen contained : —

Soluble phosphoric acid	9.15%	
Insoluble " "	4.77	
Total " "		13.92%
Total nitrogen, 1.01% = ammonia, 0.42%, i. e. nitrogen	0.35%	
nitrogen not in form of ammonia	0.66	
		1.01%
There was sand, &c., to the amount of		2.36

XI. Phosphatic Blood Guano, procured January, 1872, from the Manhattan Manufacturing and Fertilizing Company of New York, by Mr. Gardner Brewer, of Boston.

Moisture	21.25%	
Volatile matter (beside moisture) .	43.88	
Ash	34.87	
		100.00

Of matters valuable as manure the specimen contained: —

Soluble phosphoric acid	9.12%	
Insoluble " "	1.93	
Total " "		11.05%
Nitrogen		2.72%
There was sand, &c., to the amount of		1.56%

BONE-MEALS AND BONE-BLACKS.

XII. Coarsely ground Bone, bought April, 1871, of J. Breck and Son, Boston.

Moisture	8.36%	
Volatile matter (beside moisture) .	32.29	
Ash	59.35	
		100.00

The sample contained: —

22.05% of phosphoric acid, and
2.07 of sand.

XIII. Fine Bone-Meal, bought April, 1871, of J. Breck and Son, Boston.

Moisture	6.70%	
Volatile matter (beside moisture) .	19.29	
Ash	74.01	
		100.00

The sample contained: —

24.80% of phosphoric acid, and
1.48 of sand.

XIV. Bone-Meal, bought April, 1871, of William L. Bradley, Boston.

Moisture	5.53%	
Volatile matter (beside moisture) .	38.47	
Ash	56.00	
		100.00

The sample contained: —

19.40% of phosphoric acid, and
1.62 of sand.

XV. Coarse Bone-Black, obtained February, 1872, from Messrs. C. O. Whitmore and Sons, Boston.

Moisture	9.94%	
Carbon	10.40	
Ash	79.66	
		100.00

The sample contained: —

32.08% of phosphoric acid, and
0.49 of sand.

XVI. Fine spent Bone-Black, obtained February, 1872, from C. O. Whitmore and Sons, Boston.

Moisture	9.79%	
Carbon	5.80	
Ash	84.41	
		100.00

The sample contained: —

30.19% of phosphoric acid, and
2.73 of sand.

NITROGENIZED MANURES.

XVII. Blood Flour, procured January, 1872, from the Manhattan Manufacturing and Fertilizing Company of New York, by Mr. Gardner Brewer, Boston.

Volatile matter and moisture	95.02%	
Ash	4.98	
		100.00

The sample contained: —

0.80% of phosphoric acid,
11.22 of nitrogen, and
0.31 of sand.

XVIII. Dried Blood, as produced by a drying apparatus similar to the one employed by Messrs. North, Meriam, & Co., obtained December, 1871, at New Haven, by Dr. George Derby, Secretary of the Massachusetts State Board of Health.

The sample contained: —

10.38% of nitrogen.

XIX. Dried Fish-Scrap, as produced by the drying apparatus aforesaid, obtained at New Haven by Dr. George Derby, December, 1871.

Volatile matter and moisture . .	62.71%	
Ash	37.29	
		100.00

The sample contained : —

7.28% of phosphoric acid,
5.50 of nitrogen, and
0.83 of sand.

XX. Dried Tankings (slaughter-house refuse), as produced by the drying apparatus aforesaid, obtained at New Haven, December, 1871, by Dr. George Derby.

Volatile matter and moisture . .	89.95%	
Ash	10.05	
		100.00

The sample contained : —

2.56% of phosphoric acid,
7.25 of nitrogen, and
4.02 of sand.

XXI. Blood, Bone, and Meat-Dust Fertilizer, from Messrs. North, Meriam, & Co., East Cambridge, obtained April, 1872.

Moisture and volatile matter . .	56.72%	
Ash	43.28	
		100.00

The sample contained : —

16.58% of phosphoric acid, and
3.80 of nitrogen.

XXII. Blood, Bone, and Meat-Dust Fertilizer, from Messrs. North, Meriam, & Co., East Cambridge, obtained September, 1872.

Moisture and volatile matter . .	64.52%	
Ash	35.48	
		100.00

The sample contained : —

12.08% of phosphoric acid,
4.89 of nitrogen.

PEATS.

XXIII. *A.* Peat, from Thomas Motley, Esq., Bussey Farm.

Moisture	15.24%	
Volatile matter (beside moisture)	77.78	
Ash	6.98	
		100.00

The sample contained: —

1.20% nitrogen.

B. Peat, from Henry Saltonstall, Esq., Lynnfield.

Moisture	12.50%	
Volatile matter (beside moisture)	74.52	
Ash	12.98	
		100.00

The sample contained: —

0.16% of phosphoric acid, and
1.66 of nitrogen.

C. Mud, from a pond-hole, from Henry Saltonstall, Esq.

Moisture	9.24%	
Volatile matter (beside moisture)	53.82	
Ash	36.94	
		100.00

The sample contained: —

0.35% of phosphoric acid, and
1.47 of nitrogen.

D. Peat, from Mr. F. H. Appleton, West Peabody.

The sample contained: —

1.28% of nitrogen.

The prices charged for the commercial fertilizers of the foregoing list range from $ 50 to $ 60 per ton for the superphosphates, and from $ 40 to $ 70 per ton for the dried tankings and blood. But the probable value to the farmer of the several substances may be calculated with tolerable accuracy, as will appear from the following considerations.

The only constituents the value of which as manure it is worth

while to calculate in any of the substances analyzed, are phosphoric acid and nitrogen, and it is therefore the money worth of these two ingredients which is to be estimated.

In the spring of 1872 insoluble phosphoric acid could be bought in Boston at five cents per pound, in the form of waste bone-black. The price of this substance, containing thirty per cent of phosphoric acid, as stated above in analysis No. XVI., was one and a half cents per pound.

Bone-ash from South America containing seventy per cent of pure bone-phosphate of lime is sold in London at from £ 6 15 *s.* to £ 7 the long ton, equivalent (1872 – 73) to about $ 32 in our money per ton of 2,000 pounds containing 644 pounds of phosphoric acid. Since it is fair to suppose that bone-ash could be imported into Boston about as cheaply as it can be carried to London, it may be assumed that the pound of insoluble phosphoric acid can be had in this form also for five cents.

As contained in bone-meal, insoluble phosphoric acid has been valued by Professor Johnson * and others at six cents per pound. It is believed by many chemists that, pound for pound, the phosphoric acid in bone-meal is worth more to the farmer than that in bone-ash or in bone-black. However that may be, the last estimate (six cents per pound) has the advantage of being more generally applicable than either of the others. Since bone-meal may be procured in almost any locality, a valuation of phosphoric acid based upon the cost of this material will manifestly be of a less local and more general character than the estimates based upon bone-black or bone-ash, which are to be had at cheap rates only in the vicinity of sugar-refineries or of seaports.

It appears then that insoluble phosphoric acid may be reckoned as worth from five to six cents per pound.

Sixteen and a quarter cents per pound may be allowed for *soluble* phosphoric acid, this being the valuation adopted by Professor Johnson. It is a liberal allowance in view of the strong probability that soluble phosphoric acid can be imported from Europe at a lower rate.

Thirty cents per pound may be allowed for *nitrogen* in the form of ammonium compounds and for that in blood, this estimate being somewhat higher than the price at which the pound of active nitrogen can usually be bought either in the form of guano or of nitrate of soda.

* Connecticut Agricultural Reports for 1870.

Twenty-five cents per pound may be allowed for the nitrogen in tankings and in bone-meal.

Twenty cents per pound may be allowed for the nitrogen of unknown quality concealed in the superphosphates. Nitrogen of fair quality can, in fact, be bought in this vicinity for much less money than this in the form of unground fish-pomace, as will be shown directly.

Calculating from these data the approximate values of the samples of fertilizers analyzed, we obtain the following table; —

No. of the sample.	Calculated value per ton.	Price charged per ton.
I.	$ 29 – 30	$ 55
II.	23 – 25	55
III.	34½ – 36½	50
IV.	About 44	50
V.	41 – 43	60
VI.	37 – 38½	60
VII.	About 44	60
VIII.	20½ – 22	60
IX.	33½ – 34½	60
X.	39 – 40	60
XI.	About 48	50
XII. *	40 – 45	50
XIII. *	40 – 45	60
XIV. *	40 – 45	50
XV.	32	—
XVI.	30	30
XVII.	68	70
XVIII.†	63	—
XIX.†	30	—
XX.†	39	—
XXI.†	35½ – 39	—
XXII.	36½ – 39	40
XXIV. (See beyond.)	34 – 35	15

The estimates of the value of the pound of nitrogen given above, and particularly those relating to the nitrogen contained in tankings

* Good bone-meal contains on the average 22 per cent of phosphoric acid and 3.8 per cent of nitrogen. Hence the value of the samples analyzed may be taken at from $ 40 to $ 45, as above.

† The samples marked with a dagger were experimental products. They were not for sale.

and in bone-meal, and to that of "unknown quality," are probably much too high for regions like New England, where abundant stores of nitrogen in the form of peat and pond-mud are accessible to most farmers, and can easily be made "active" and available as plant-food by fermentation in the compost-heap.

As regards the nitrogen in the superphosphates analyzed, it is doubtless to be referred in most instances to an admixture of rough "fish-scrap," otherwise called "fish-pomace," or "pogy-chum," which is the residue left after the expression of oil from the boiled flesh of the fish (*Alosa menhaden*) known as pogy, menhaden, or hardhead.

For several years past this material, brought in bulk from the State of Maine, has been procured by farmers in the vicinity of Boston at the rate of $ 15 per ton. A sample of this product obtained from Mr. William L. Bradley of Boston was found to contain: —

XXIV.	Moisture	33.68%	
	Volatile matter (beside moisture)	51.37	
	Ash	14.95	
			100.00

Of matters valuable as manure, the specimen contained: —

Phosphoric acid	5.59	
Total nitrogen, 6.42 = { ammonia, 1.85%, i. e. nitrogen		1.52%
{ nitrogen not in form of ammonia		4.90
		6.42%

There was sand, &c., to the amount of one per cent.

In a ton of such fish-scrap there would be 112 pounds of phosphoric acid, worth from $ 5.60 to $ 6.72, according as the lower or the higher estimate of the cost per pound of insoluble phosphoric acid were adopted; and 30.4 pounds of nitrogen in the form of ammonia worth $ 9 on the estimate (thirty cents per pound) above given. Hence the ninety-eight pounds of nitrogen not in the form of ammonia contained in a ton of fish-scrap would cost the purchaser either forty cents or less than nothing, according as one or the other valuation of the phosphoric acid were adopted.

In spite of the apparent absurdity thus shown of the high estimate (twenty cents per pound) given above for the pound of nitrogen of unknown quality, and of my conviction that the addition of rough nitrogenized materials to superphosphates at the manufactory is a

practice greatly to be deprecated, I have preferred to retain this figure in order to avoid the semblance of unfairness to any manufacturer, and in deference to the estimates previously published by chemists. It is possible, of course, that the nitrogenous materials in the superphosphates analyzed may not have been derived from fish-scrap, but from bone or from flesh or from tankings; and it may be that the nitrogen in these materials is more active as a fertilizer than that in fish-scrap. Moreover, the price ($15 per ton) at which fish-scrap is obtainable upon the sea-board of New England is probably much lower than it would be in the interior. Where water-carriage is not to be had, the cost of transporting this rather offensive substance would doubtless be comparatively high.

Both the analyses and the tabular estimates above given accord closely with the experience of other chemists, notably with that of Professor S. W. Johnson of New Haven, who has analyzed a large number of fertilizers during the last ten or twelve years at the instigation of the State Agricultural Society of Connecticut.* They differ, on the other hand, to a certain extent, from the statements of various manufacturers of superphosphates and of their agents and analysts, who allow a certain value per pound intermediate between $0.06 (the value of insoluble phosphoric acid) and $0.1625 (the value of soluble phosphoric acid), for whatever amount of phosphoric acid in the condition of the so-called *reduced phosphate* (2 CaO, H_2O, P_2O_5) a sample of superphosphate may contain. In favor of such allowance it is urged that the "reduced phosphate," though scarcely at all soluble in cold water, is nevertheless a little soluble in that liquid and more soluble in the acid and saline liquids of the soil than the original rock phosphate from which the superphosphate has been prepared.

I deem the practice of making such allowance wrong, for the reason that the purpose of a superphosphate is to supply *soluble* phosphoric acid to the land. From what is known of the manner in which the soluble phosphoric acid of a superphosphate is distributed and decomposed in the soil, it seems plain that this substance had much better be applied by itself without any admixture of phosphates which are

* See the Connecticut Agricultural Reports for 1858, 1869, and 1870. Compare the work entitled "American Manures," by W. H. Bruckner and J. B. Chynoweth. Philadelphia. 1872.

difficultly soluble. In this vicinity we are not justified in allowing more than the price of an equivalent weight of spent bone-black for any insoluble or difficultly soluble phosphoric acid with which a superphosphate may be contaminated.

In case the proportion of soluble phosphoric acid in a superphosphate, as indicated by analysis, is very small, the intelligent farmer will reject that material altogether, since it does not contain the chemical agent he seeks.

On the other hand, when the proportion of insoluble phosphoric acid in a superphosphate is small, it seems but justice to allow the manufacturer something for the benefit land may receive from the addition to it of a "durable" fertilizer, such as insoluble phosphate of lime (from whatever source) is known to be.

It will probably be found in most cases in which impure superphosphates are employed as manure, that the practical benefit derivable from the mixture of reduced and undecomposed phosphates, which contains the "insoluble phosphoric acid" of the fertilizer in question, may be very fairly represented by an amount of spent bone-black containing that much phosphoric acid.

It might seem at first sight that the experience of farmers as to the value of most American superphosphates must be similar to that of the chemists, and equally conclusive to the minds of the farmers; but for obvious reasons this is not the case. Few, if any, superphosphates are wholly worthless; most of them do produce a certain beneficial effect when applied to moderately good land; thus the purchaser of a sample said to be similar to No. X. of the foregoing list obtained results from using it in his garden which seemed to him highly favorable; the only trouble is that the benefit obtained is incommensurate with the money paid out. The farmer, in order to come to a definite decision upon a point like this, would have to make careful comparative experiments such as he seldom has time to attend to; and the common result seems to be that by repeated trials of various fertilizers, each as worthless as the others, he practically becomes habituated to the use of materials which he has no good reason to esteem.

At all events, the continued sale, year after year, of enormous quantities of very poor materials shows conclusively that there must be hosts of farmers who are still unconscious that their money could be spent to better purpose. It is by analysis alone that the disreputable

character of the American superphosphates and the enormous differences, in respect to price and worth, which exist between them and those ordinarily sold in Europe, can be made manifest with conclusiveness and precision; but it would be seldom worth while for any single farmer to go to the expense of having analyses made of the fertilizers in his market, and practically it does not seem to do much good to publish lists of analyses like the one presented herewith.

It is said to be a matter of common experience that when a fertilizer has once been publicly commended in this country by a responsible chemist, its quality is apt to undergo a rapid depreciation. On the other hand, the vendors of manures which have been pronounced bad take small pains to improve the quality of their goods, but protest that their processes of manufacture have been perfected, and that the material now sold is excellent.

Moreover, in view of the multitude of analyses which have now been made by chemists, — at great cost of skilled labor, — it would seem as if the time had come for striking at the root of the matter, in short, for taking some definite action, by which to amend the existing system of making and selling manures in this country.

The subject is really one of very grave and general importance, both from the scientific and the political point of view. So far as the actual money loss to the farmers is concerned, it may be accounted a light, or at all events a comparatively unimportant, misfortune that they should pay out unwisely some hundreds of thousands of dollars every year to the dealers in manures; but it is a very serious matter that the farmers are by this very fact of injudicious purchase made to persist in their ignorance, and are prejudiced more and more strongly every year against those sources of knowledge which would not only protect them from this particular form of loss, but also must be the principal means of agricultural improvement. There can be no question but that the low quality of the commercial fertilizers now commonly sold in our markets exerts a most pernicious influence upon the growth of all American schools of agriculture, and obstructs agricultural progress throughout the land. It is idle to expect farmers to lend a ready ear to the teachings of Science so long as they continue to suffer in her name, as they do now every time they pay an undue price for a fertilizer said to have been prepared in accordance with chemical theory. The experience of the European schools of agricul-

ture shows conclusively that there is no one thing which tends more strongly to excite an interest in the sciences bearing upon agriculture, among the farmers of a district, than the introduction into its markets of really good fertilizing materials.

There would seem to be a simple method of overcoming the present difficulty, namely, by procuring importations from Europe of guaranteed fertilizers of good quality and encouraging the sale of such fertilizers in small packages, as well as by the usual large quantities. If a powerful society were to engage in this work, it would probably be easy to force up the standard of the American manufacturers to the proper degree, and to introduce the system of selling by warranty.

The usual German standards for superphosphates are ten, fifteen, and twenty per cent of soluble phosphoric acid, according as the superphosphate has been made from a mineral product, from bone-black, or from a phosphatic guano. As to the price of such materials, I can only say that I wrote in the spring of 1871 to Dr. L. C. Marquart, of Bonn, a responsible chemical manufacturer with whom I have had frequent dealings, asking the terms upon which he could deliver superphosphate alongside ship at Rotterdam. He replied in these words: —

"With regard to superphosphate of lime, I have corresponded with the most respectable houses of that branch, and am able to offer you as follows: Superphosphate containing

10%	of soluble	phosphoric	acid, at	5 *s.* 4 *d.*	per	cwt. (English.)
15	"	"	" "	8 *s.* 5 *d.*	"	"
20	"	"	" "	10 *s.* 6 *d.*	"	"

Free at Rotterdam, packages included, against short remittance on London. If you wish to get a merchandise of more or less per cent, the price will be in proportion. The contents of not soluble phosphoric acid which is existing in the superphosphate of lime will not be taken into consideration; the soluble acid, however, will be warranted.

"Very truly yours,
"L. C. Marquart."

I may here mention an observation of some interest that may perhaps serve to place the subject of artificial manures in a new light, and to illustrate one at least of their merits.

In December, 1871, I noticed one day in the "potting-house" of the horticultural department a small heap of dung that had just been brought in from some hen-roost. This dung was firmly frozen, so that its several particles were as hard and as little coherent as gravel. Two or three days later I happened to see the same heap again, and found it alive with maggots.

A quantity of the dung, together with its inhabitants, was immediately sent to Mr. F. G. Sanborn, the entomologist, who replied in the following terms :—

BOSTON, MASS., December 10, 1871.

MY DEAR SIR, — I have given a close examination to the larvæ you sent me a day or two since. I find them to be the young, or "maggot," of a species of fly closely allied to the common "house fly," but perhaps belonging to the genus *Anthomgia*, — a set of flies which hover about flowers when winged, but which feed in the larva-form on decaying matter in general. To this genus belong the "Onion maggot" so destructive in some sections, and a great variety of species more or less injurious to agriculture. The eggs laid by the parent fly in early autumn were probably hatched by the increase of temperature some months earlier than usual. I shall endeavor to rear the creatures to their perfect condition, when I can report still more certainly. You are doubtless aware that the difficulty of identifying *species* from the *larvæ* alone is very great, so few even of our commoner forms have been conscientiously reared.

Very truly yours,

FRANCIS G. SANBORN.

PROFESSOR F. H. STORER, *Bussey Institution.*

Mr. Sanborn has since assured me, by word of mouth, that he succeeded in rearing perfect flies from the larvæ in question, and that his suspicion as to their injurious character was confirmed.

He will undoubtedly publish the results of his investigation in due season. I allude to the matter merely because of its manifest bearing upon the use of those artificial fertilizers which must necessarily, from the manner of their preparation, be free from the eggs of insects.

It is a matter of the commonest observation that the richer kinds of dung, such as that of man and of the hog, are liable to be flyblown ; but it seems to be less generally understood that the dungs in question may and do actually serve as hot-beds and nurseries for the production of insects which are to be classed among the worst enemies of growing crops.

No. 2. — *A Record of Results obtained on analyzing several Samples of American "Shorts" and "Middlings," with Remarks on the Average Composition of Bran*,* by F. H. Storer, Professor of Agricultural Chemistry.

The refuse husk or skin of the grain left when wheat is ground and sifted to flour has often been commended as food for cattle, and is, in fact, very extensively used for that purpose, in spite of some misconceptions and prejudices which still survive. In the American markets this so-called refuse product now holds a place as well assured as that of either of the grains. Enormous quantities of it are distributed every day to all parts of the country. I have thought it worth the while to have analyses made of a number of samples of the different forms of bran, taken from various localities, in order to determine whether any noteworthy diversities of composition could be detected in the products of different regions, and also for the sake of contrasting the average composition of bran with that of the other kinds of fodder with which it is likely to come into competition.

In order to a clear understanding of the subject, the meaning of the terms "shorts," "feed," and "middlings" had better be first defined as well as may be. In point of fact, neither of the terms seems to have any very precise signification. At all events, they are used somewhat loosely in this vicinity.

Feed seems to be a generic name which may include any wheat product separated from flour by the bolting or sifting processes of the miller. It is, however, sometimes used synonymously with *fine-feed*, which term is generally restricted in Boston to a special kind of feed of homogeneous meal-like character, finer than shorts and coarser than middlings.

Shorts is the coarser part of the refuse separated from wheat in the process of making flour. The term "shorts," as used in this vicinity, seems indeed to be absolutely synonymous with "bran," as used in English literature and the language of every-day life. In this paper I regard the English bran, American shorts, French *son*, and German *Kleie* as synonymous.

* This article was presented to the trustees of the Massachusetts Society for Promoting Agriculture, in January, 1873.

Middlings is a meal-like product, much finer than shorts and much coarser than flour; it may be described as standing midway between the two, as its name imports.

The term *mill-stuff* is applied in Boston to a mixture of shorts and middlings which includes everything not flour which has been separated from wheat at the mills of that city. In Chicago the same product is called *mill-feed.*

Ship-stuff seems to be a Southern term, analogous to, if not identical with, the Northern mill-stuff. The sample of ship-stuff examined in this laboratory was manifestly a mixture of shorts and middlings in some unknown proportions. It was much finer than shorts, though coarser than middlings. Particles of shorts could be seen interspersed through it.

It is noteworthy that the use of the terms "shorts" and "feed" seems to be essentially American. The words are at all events sufficiently unlike the English terms "bran," "sharps," "boxings," and "pollard," which, with the exception of the first, are perhaps never used in the United States. It might have been supposed that the term "shorts" originated in Pennsylvania or New York by translation from the German *Kurzkleie*, or the Dutch *Kort*, were it not for the fact that the English archæologist, Halliwell, in his "Dictionary of Archaic and Provincial Words," defines the word "shorts" as follows: "Coarse flour: The term is also applied to the refuse of corn [i. e. wheat or other small grain] in various dialects." It is to be remarked, moreover, that neither the German nor the Dutch word given above is the precise equivalent of the English word "bran." The term "middlings" is used by London millers as well as in this country, though apparently in a somewhat different sense.

I am indebted to Mr. Elijah H. Luke, grain-dealer of Cambridgeport, for the samples analyzed, and to that gentleman, as well as to other members of the trade, for information concerning the subject. The samples were obtained and analyzed in the autumn of 1872.

The object of the analyses being merely to determine the foddering value of the substances examined, I have resorted to the processes ordinarily employed to that end, as set forth by Professor Henneberg, in *Die landwirthschaftlichen Versuchs-Stationen*, 1864, **6**, 496. I have endeavored in this way to obtain results comparable with those which have been obtained by chemists who have analyzed other kinds

of fodder. See, for example, Wolff's table of the average composition of fodder in Johnson's "How Crops Grow," New York, 1868, p. 385.

The following table shows the composition of the substances examined in the Bussey Laboratory. They were all commercial products derived from wheat grown in 1872.

	St. Louis Shorts.	Illinois Shorts.	Michigan Shorts.	Mean of the three kinds of Shorts.
Water	12.23	10.96	11.77	11.65
Ash (free from C and CO_2)	4.53	4.24	4.06	4.28
Albuminoids	12.06	11.13	12.75	11.98
Carbohydrates (including fat), by difference	64.06	66.38	60.95	63.80
Cellulose (free from ash)	7.12	7.29	10.47	8.29
	100.00	100.00	100.00	100.00
Dry organic matter	83.24	84.80	84.18	84.07
Fat	4.01	4.06	4.65	4.24
Nitrogen	1.93	1.78	2.04	1.92

	St. Louis Middlings.	Illinois Middlings.	Mean of the two kinds of Middlings.
Water	12.08	13.30	12.69
Ash	1.57	2.71	2.14
Albuminoids	11.06	10.13	10.60
Carbohydrates (including fat), by difference	71.72	68.51	70.11
Cellulose (free from ash)	3.57	5.35	4.46
	100.00	100.00	100.00
Dry organic matter	86.35	83.99	85.17
Fat	2.51	3.71	3.11
Nitrogen	1.77	1.62	1.70

	St. Louis Ship-Stuff.	Mean of the Middlings and Ship-Stuff.
Water	11.81	12.25
Ash	2.25	2.20
Albuminoids	11.12	10.86
Carbohydrates (including fat)	69.23	69.67
Cellulose (free from ash)	5.59	5.02
	100.00	100.00
Dry organic matter	85.94	85.56
Fat	2.77	2.94
Nitrogen	1.78	1.74

In explanation of these analyses it may be said that the term "albuminoids" includes gluten, albumen, casein, etc., i. e. all the nitrogenized, flesh-forming, or so-called plastic elements of nutrition contained in the substances examined.

"Carbohydrates" includes, besides fat, starch, dextrin, sugar (if any there be), and the more tender and easily decomposable portion of the woody fibre. The term, therefore, represents a class of substances which go to nourish the animal in one and the same way, and which, excepting fat, are generally supposed to be of equal or very nearly equal values for that purpose. "Fat" is given by itself in a separate line because of its acknowledged superiority to the other carbohydrates as an article of food. It is to be remarked that the fat of bran, as dissolved out by ether, is remarkably pure and of firm consistence. It will be noticed that the analyses illustrate the fact observed long ago by chemists that there is much more fat in coarse than in fine bran. Thus I find, on the average, four and a quarter per cent of fat in American shorts, and less than three per cent, on the average, in the middlings and ship-stuff. Dumas, Boussingault, and Payen (*Annales de chimie et de physique*, 1843, **8**, pp. 86, 87) found:—

In wheat flour	1.40% of fat.
In fine bran	4.80 "
In coarse bran	5.20 "

The observations of Johnston, in his "Lectures on the Applications of Chemistry to Agriculture," New York, p. 530, are analogous. He found the "pollard" of wheat to yield more than twice as much oil as the fine flour obtained from the same sample of grain, and in four portions separated by the miller from a superior sample of wheat grown at Durham he found (*loc. cit.*, pp. 530, 601) the following amounts of fat:—

In the fine flour	1.5
" " pollard	2.4
" " boxings	3.6
" " bran	3.3

I do not know in what proportions shorts, fine-feed, and middlings are produced in the mills of this country. So far as relates to the proportion of flour (of first quality) to feed, the current statement is that five bushels or three hundred pounds of wheat yield one barrel or one hundred and ninety-six pounds of flour. The loss through evapo-

ration as the grain is heated between the mill-stones amounts on the average to two pounds for each bushel of wheat, and there is left altogether ninety-four pounds of shorts, fine-feed, and middlings as the refuse of the three hundred pounds of wheat. Stated in terms of per cent, this result will read as follows : —

Flour	65.34	
Feed	31.33	
Loss	3.33	
		100.00

Liebig, in his *Chemische Briefe*, 4[te] Aufl., 1859, **2**, 169, says that the best mills yield from twelve to twenty per cent of bran (ten parts of coarse bran, seven parts of fine bran, and three parts of bran meal), and ordinary mills as much as twenty-five per cent. According to Knapp (as cited by v. Bibra), one hundred pounds of wheat ground in an old-fashioned mill yields : —

Flour	55 lbs.
Middlings	18
Fine-feed	9
Bran	18
	100

While one hundred pounds of wheat ground in a modern mill near Paris yields : —

Flour of various grades	78 lbs.
Middlings	10
Fine-feed	3
Bran	7
Loss and waste	2
	100

Professor Johnston (on p. 498 of his book cited above) makes the following statement. Three lots of good English wheat ground at Durham gave per cent respectively : —

Fine flour	74.2	75.1	77.9
Boxings	9.0	8.3	6.1
Sharps	5.8	6.6	5.6
Bran	7.8	7.0	6.9
Waste	3.2	3.0	3.5
	100.00	100.00	100.00

For a tabular statement of observations on the amount of flour obtained from wheat, as recorded by different authorities, see Lawes and Gilbert's pamphlet "On some Points in the Composition of Wheat-Grain, its Products in the Mill, and Bread," London, 1857, p. 42.

From the analyses of Fürstenberg (*Journal für praktische Chemie*, 1844, **31**, 195), of Poggiale (*Comptes-Rendus*, 1853, **37**, 174), Oudemans (*Mulder's Scheikundige Verhandelingen*, as cited below), and von Bibra (in his *Die Getreide Arten und das Brod*, Nürnberg, 1861, p. 217), it appears that the carbohydrates in bran include from twenty-two to twenty-nine per cent of starch, and from five and a half to eight and a half per cent of dextrin. The proportion of sugar in bran appears to be very small. Millon (*Annales de chimie et de physique*, 1849, **26**, 34) says there is not more than two per cent of sugar, and Poggiale says 1.91 per cent. Fürstenberg declares that he could detect no sugar in wheat bran of excellent quality, and reports that investigations made in Mitscherlich's laboratory led to negative results like his own. Oudemans does not admit its presence, but v. Bibra reports four and one third per cent of sugar.

For the sake of comparison I have collected and tabulated upon the opposite page a number of analyses of European brans, made by various chemists.

These foreign analyses seem to have been made by processes similar to those employed in this laboratory, excepting in some points of detail. Thus, with the exception of analyses Nos. IV., IX., and XIII., the item "ash" probably refers in all cases, as it certainly does in most, to "crude ashes" contaminated with particles of carbon, such as is usually left when a vegetable substance rich in phosphates is ignited. In the American shorts the mean percentage of such crude ash, obtained after careful and long-continued ignition, was 5.23. The amount of carbonic acid in this crude ash was always exceedingly small. Sometimes the amount was hardly appreciable.

The item "cellulose" evidently refers to cellulose contaminated with a certain amount of inorganic material. This remark is true, not only of analysis No. IV., as appears from Bähr and Wolff's description of their process, but probably of all the other analyses. In the determinations of Millon, who used chlorhydric acid for estimating cellulose, and in those of Peligot, who used sulphuric acid of some considerable strength, the proportion of ash left in the cellulose may have

ANALYSES OF EUROPEAN BRANS.

	I.	II.	III.	IV.	V.	VI.	VII. *a*	VII. *b*	VIII.	IX.	X.	XI.	XII.	XIII.
Water	13.80	10.30	13.80	15.05	13.90	12.70	14.07	14.27	12.70	11.33	13.06	13.10	14.07	...
Ash	5.60	...	...	4.30	5.70	5.50	6.52	6.26	5.62	4.10	7.30	7.30	...	3.9
Albuminoids	...	12.48	14.38	13.19	14.90	13.00	13.46	12.68	17.37	19.96	18.12	19.30	20.88	...
Carbohydrates (including fat)	...	...	...	54.15	55.80	58.80	...	...	54.32	55.35	...	...	...	...
Cellulose	9.20	...	...	13.31	9 70	10.00	...	...	9.99	9.26	...	...	...	...
				100.00	100.00	100.00			100.00	100.00				
Dry organic matter	...	...	...	80.65	80.40	81.80	...	...	81.68	84.57	...	...	...	...
Fat	4.10	2.82	...	...	3.64	2.88	2.46	2.88	3.79	4.51	5.20	4.70	...	...
Nitrogen	...	...	2.30	2.11	2.38	...	2.07	1.96	2.78	...	2.90	...	3.34	...

	XIV. *a*	XIV. *b*	XIV. *c*	XIV. *d*		XV. *a*	XV. *b*	XV. *c*	XV. *d*	XV. *e*	
Cellulose	7.0	7.8	9.3	8.0	i. e. from 7 to 9⅓	8.72	10.98	9.78	8.72	7.53	i. e. from 7.5 to 11
Fat	from 3 to 3.5.										

I. Wheat-bran, analyzed by Kekulé, *Liebig's Chemische Briefe*. 4te Aufl. II. 169.
II. Wheat-bran, analyzed by Fürstenberg, *Journal für praktische Chemie*. 1844, **31**, 195.
III. Wheat-bran, analyzed by Boussingault. See his Rural Economy. New York, 1865, p. 408.
IV. Wheat-bran, analyzed by Bähr and Wolff, *Agricultur-chemische Untersuchungen* (zu Möckern). *Zweiter Bericht*. Leipzig, 1853, p. 13.
V. Bran, from soft wheat of North of France, analyzed by Millon, *Annales de chimie et de physique*. 1849, **26**, 34.
VI. Wheat-bran, analyzed by Poggiale, *Comptes-Rendus* 1853, **37**, 174, and **49**, 129; the cellulose by Peligot's method.
VII. *a*, "Wheat-bran," *b*, "Wheat-shorts," analyzed by Oudemans, *Mulder's Scheikundige Verhandelingen en Onderzoekingen*. Rotterdam, 1857, page 16 of the *Onderzoekingen*, at the end of the volume.
VIII. Wheat-bran, analyzed by v. Bibra. See his *Die Getreidearten und das Brod*, pp. 214, 217, 280; the cellulose by Peligot's method.
IX. Wheat-bran, analyzed by Wicke, *Hofmann's Jahresbericht*. 1865, **8**, 313.
X. The coarse wheat-bran mentioned on p. 28, analyzed by Dumas, Boussingault, and Payen, *Annales de chimie et de physique*. 1843, **8**, pp. 86, 87.
XI. Mean of six samples of wheat-bran, analyzed by Johnston, cited in Appleton's New American Cyclopædia. **3**, 635.
XII. Frapoli, *Annalen der Chemie und Pharmacie*. 1854, **91**, 108.
XIII. Wheat-bran, Louyet, *Journal für praktische Chemie*. 1850, **49**, 256. A good ash determination.
XIV. Four samples of wheat-bran, analyzed by Peligot, *Annales de chimie et de physique*. 1850, **29**, 31.
XV. Various samples of wheat-bran, analyzed by Millon (*loc. cit.*, p. 26.) *b* was a bran from a mixture of hard and soft wheat, but all the other samples were from the soft wheat of the North of France.

been smaller than in the other cases, but in every instance some ash seems to have been counted as cellulose. Now, the average amount of ash in the crude cellulose of American shorts was found to be equal to 0.33 per cent of the weight of the original bran; and if we deduct this quantity from the mean (9.00) of the fourteen foreign determinations of cellulose (excluding No. IV., which is exceptionally high), we obtain the number 8.67, which agrees very well with that (8.29) found for the American shorts.

As regards "albuminoids," it is not easy to obtain a mean which shall accord closely with all the analyses. It would almost seem as if there were two classes of bran, distinguishable by the different amounts of albuminoids contained in them. Thus, the analyses II. to VII. show from twelve and a half to nearly fifteen per cent of albuminoids, in the mean 13.44, while the analyses VIII. to XII. show from seventeen and one third to nearly twenty-one per cent. The number 13.44, which accords well enough with the mean percentage of albuminoids found in the American shorts, undoubtedly represents very nearly the average proportion of these substances contained in commercial bran. I believe the higher numbers to be either exceptional or unreliable. Since American bran is probably, as a general rule, less thoroughly freed from flour than European bran, it is not surprising that it should contain a somewhat smaller proportion of albuminoids.

Some explanation of Wicke's analysis may perhaps have been given in his original paper, but I am unable to refer to the journal which contains it. The analyses of Johnston are old, and although his determinations of water and fat are undoubtedly very near the truth, it is not at all improbable that those of albuminoids and ash were made by untrustworthy processes. The analysis of Dumas and Boussingault is likewise old, and it is not unlikely that the bran examined by these chemists was of exceptional character, as the large proportion of fat found in it would tend to show. It may be, too, that their process of analysis was faulty.

The determinations of Frapolli and of v. Bibra seem, on the other hand, to have been made with care and by approved processes. It is probable, however, that their brans were really of exceptional character, since it is to be inferred from their statements that the materials analyzed were prepared expressly for that purpose. It would not be

surprising that bran, which has been very carefully freed from flour, should contain an unusually large proportion of albuminoids. The mere fact of their bran having been fresh, i. e. recently separated from the wheat, may possibly account for the high percentages of nitrogen found by Frapolli, v. Bibra, and Wicke; but it is to be observed in this connection that most of the other analyses were of "commercial bran." The observations of Lawes and Gilbert, in their pamphlet "On some Points in the Composition of Wheat-Grain, its Products in the Mill, and Bread," London, 1857, p. 30, tend to support this view, inasmuch as the bran examined by them was prepared purposely for their investigations. These experimenters found in the four grades of bran-products between "coarse sharps" and "long bran," inclusive, from 2.39 to 2.58 per cent of nitrogen, or from 14.94 to 16.13 per cent of albuminoids (in the mean* 15.54 per cent).

* I regret that my ignorance as to the meaning of the technical terms employed by English millers prevents me from placing these determinations in the table which has been given above. The following is a statement of the results of Messrs. Lawes and Gilbert, as set forth on pages 30 to 32 of their pamphlet.

Kinds of mill products.	Per cent of flour and of feed obtained from the air-dried grain.	Per cent in the several products.		
		Of ash.	Of nitrogen.	Of albuminoids.
Flour from 1st wire . .	51.2	0.71	1.63	10.19
Flour from 2d wire . .	24.8	0.74	1.69	10.56
Flour from 3d wire . .	1.7	0.82	1.78	11.13
Tails	1.6	1.04	1.86	11.63
Fine sharps or middlings	3.3	2.19	2.21	13.81
Coarse sharps	3 3	3.93	2.58	16.13
Fine pollard	1.8	5.46	2.44	15.25
Coarse pollard	6.7	6.56	2.42	15.13
Long bran	5.0	7.14	2.39	14.94
Loss	0.6	...	...	...

It is noteworthy that the highest proportion of nitrogen was found, not in the very coarsest kinds of bran, but in the somewhat finer grade called "coarse sharps." Messrs. Lawes and Gilbert remark in this connection that "the indications of the figures are consistent with such observations as have been recorded regarding the structural composition of wheat-grain, it being stated that the greatest concentration of nitrogenous compounds is immediately below the pericarp itself, and we should expect that the longer bran would have less of the more internal matters adherent to it." To which may be added the fact, explained further on, that the wheat used for this set of experiments was of such character that it permitted an

There is reason to believe that bran is liable to lose a part of its nitrogen by keeping, and in this way to deteriorate in value, both when stored and when transported long distances. Millers and grain-dealers are careful not to allow any very considerable quantity of bran to accumulate upon their premises, because of its known tendency "to heat" and "to shrink," or lose weight. For the same reason they avoid throwing it into heaps. I am assured that a few tons of bran piled up and left to itself will quickly become hot, and waste away to the extent of perhaps twenty per cent of its original weight. At the same time it loses its light, mobile character, and settles down to a tolerably coherent mass, from which well-defined pieces can be cut out with the shovel. All this is good chemical evidence, which proves that bran ferments easily. But in such process of fermentation the flesh-like albuminoids would be the first among the ingredients of bran to suffer decomposition and be lost in the form of gas. It is not impossible that one explanation of the somewhat smaller proportion of albuminoids in the American brans is to be found in the fact of their having been tightly packed during the long journey to market from the place of their production.

On the other hand, it is not unlikely that the samples of bran so exceptionally rich in albuminoids may have come from wheat which grew on land very rich in available nitrogen, or upon land that had been highly manured. The influence of nitrogenized manures in increasing the proportion of albuminoids in crops has been often noticed, but Messrs. Lawes and Gilbert (*loc. cit.*, pp. 12, 13, 21, 28, 30, 32) have observed, in addition to this, that grain grown with nitrogenous manuring in good seasons, which permitted the crop to be well developed and matured, allowed a better separation of the flour and yielded a cleaner bran than the grain of poorer crops. Their observations also confirm the general opinion that old wheat yields up its flour better than new. In a large number of trials upon different samples of wheat they got on the average no more than seventy per cent of flour from the three first wires, while the old and well-matured wheat from which their bran just now alluded to was obtained gave seventy-seven and three-quarters per cent. It is not surprising, therefore, that brans

unusually perfect separation of the several products. An uncommonly large yield of flour was obtained, and the bran was remarkably free from flour. The large percentage of ash found in these bran-products also attests their freedom from flour.

exceptionally rich in albuminoids should now and then be met with; but I think they do not fairly represent the commercial article, and I have therefore little hesitancy in excluding from my estimation of the average composition of bran the determinations of albuminoids given in analyses Nos. VIII. to XII.

If due allowance be made for all these sources of error and difference, and for the smaller proportion of water reported in the American brans, — due in part, perhaps, to the dryness of our winter climate as compared with that of Europe, and probably in part to the fact that analysts are not in accord as to the best temperature for drying organic substances,* — it will be seen that the average composition of the European brans is very nearly the same as that of the American. The following table shows the average composition of European brans thus deduced from selected determinations.

	No. of determinations (or rather of statements of results) from which the mean has been deduced.	Mean.
Water	13	13.24
Ash (free from C and CO_2)	3	4.10
Albuminoids	7	13.44
Carbohydrates (including fat), by difference		60.22
Cellulose	14	9.00
		100.00
Dry organic matter, by difference		82.66
Fat	12	3.62

This result differs appreciably in several particulars from Wolff's estimate as stated in the fodder-tables in Johnson's "How Crops Grow," p. 387, and is, I think, more nearly correct. I regret my present inability to consult Professor Wolff's original discussion of

* The percentage of water in the American brans, as above stated, was determined by drying at 100° C. But many analysts prefer to dry at 110°. A couple of trials, made specially to determine how large an amount of water would be expelled at 110° from bran that had previously been dried at 100°, gave the following results: —

2.0486 grammes of Michigan shorts gave	11.89%	of water when dried at	100°
" " " " "	12.54	" " " " "	110°
Difference	0.65		
2.8835 grms. of St. Louis middlings gave	12.21%	of water when dried at	100°
" " " " "	12.89	" " " " "	110°
Difference	0.68		

this matter; but it is plain that in estimating his mean for the item "cellulose" he has admitted some determinations which, as I shall show further on, are not comparable with the cellulose determinations in the other parts of his table. His estimate of albuminoids may possibly be a little too high. He has evidently included one or two of the determinations which I have thought best to disregard for the reasons above stated.

It is plain, from all that has been said, that bran, as found in commerce, is a fodder of tolerably constant composition, as well as of high nutritive value.

In the following table the composition of bran is contrasted with that of oats, barley, maize, brewers' grains, and hay; also with that of the common whiteweed, or ox-eye daisy, as determined in this laboratory. The analyses of oats, barley, brewers' grains, and hay are copied from Wolff's table in Professor Johnson's "How Crops Grow," p. 385; that of maize is the mean of several analyses of the yellow corn of New England, made at the New Haven Laboratory by Professor Atwater (see "American Journal of Science," 1869, **48**, 352).

	Water.	Ash (free from C and CO_2).	Albuminoids.	Carbohydrates, including fat.	Cellulose.	Dry organic matter.	Fat, i. e. matter soluble in ether.
American shorts .	11.65	4.28	11.75	64.42	8.29	84.07	4 24
European bran . .	13.24	4.10	13.44	60.22	9.00	82.66	3.62
American middlings and ship-stuff	12.25	2.20	10.86	69.67	5.02	85.56	2.94
Oats	14.30	3.00	12.00	60.90	10.30	82.70	6.00
Barley	14.30	2.60	9.50	66.60	7.00	83.10	2.50
Maize	9.30	1.41	9.67	77.17	2.46	89.29	5.04
Brewers' grains . .	76.60	1.20	4.90	11.10	6.20	22.20	1.60
Hay	14.30	6.20	8.20	41.30	30.00	79.50	2.00
Dried whiteweed, cut at the time of flowering	10.87	6.44	7.00	44.69	31.00	82.69	2.42

Several chemists who have investigated bran with the view of estimating its value as human food have argued, with some degree of truth, that the proportion of cellulose as above given tends to convey a false impression, by implying that there is a larger amount of starch, dextrin, or sugar in bran than can be found by direct analysis. In

other words, they complain that a considerable quantity of tender and easily soluble cellulose is classed precisely as if it were starch or sugar. Thus Poggiale and Oudemans, and after them v. Bibra, regarding bran as a possible admixture in bread, have been at pains to exclude from our term "carbohydrates" everything but starch, dextrin, sugar, and fat. Poggiale and Oudemans in particular have estimated "cellulose" not by treating the bran alternately with dilute acid and alkali after Millon, Peligot, and the generality of chemists, but by means of diastase (used to remove starch) and alkali. The matter recorded as "cellulose" in their analyses is consequently not comparable with the substance to which that term is ordinarily applied. Their analyses may be stated as follows: —

	Poggiale.	Oudemans.	
		a	*b*
Water	12.67	14.07	14.27
Ash	5.51	6.52	6.26
Albuminoids	13.00	13.46	12.68
Dextrin, starch, and sugar	31.31	31.63	34.98
Woody fibre	34.58	30.80	27.21
Fat	2.88	2.46	2.88

These analyses have comparatively little interest in the present connection. They are given merely for the sake of showing what has been done by chemists who have looked at the subject from another point of view. It is to be remembered that we are here considering bran as food for cattle, and that the analyses tabulated on the preceding pages do compare one kind of cattle food with another. Their sole purpose is to enable us to contrast the different kinds of fodder. As regards the item "cellulose," for example, the table shows conclusively that while hay contains thirty per cent of woody fibre, so compact that it can withstand the tolerably long-continued action of dilute acid and alkali; that while oats contain ten and one third per cent, brewers' grains 6.2 per cent (in a total of only twenty-two and one quarter per cent of dry organic matter), and dry whiteweed thirty-one per cent of this resisting substance, bran yields no more than eight and one third per cent of it when exposed to precisely similar treatment, and maize only about three per cent. The method ordinarily used for determining cellulose is undoubtedly far from being perfect, as I may have occasion to show in a future communication; but, with all its faults, it certainly does enable us to make many useful comparisons like those

which have been given above. It is perfectly fair, moreover, to class as "carbohydrates" all that portion of the woody fibre of vegetables which is easily disaggregated and dissolved by dilute acids; for the researches of a number of German investigators have shown that a large proportion of even the most compact forms of cellulose is digested without difficulty by animals, particularly by the ruminants.

I have not found it easy to obtain any very precise estimates of the quantities of bran-products used in this vicinity as fodder for the different kinds of animals. In Boston and in the adjacent cities very considerable quantities of shorts are fed to horses as an admixture in their daily ration of Indian meal or cracked corn; in some cases even as an addition to oats. An occasional bran-mash is given by many hostlers in addition to the smaller daily allowance. In some stables, where Indian meal is fed to horses in conjunction with cut hay, a certain proportion of "fine-feed" is added to the mixture as a laxative agent. But, with this exception, it would appear that nothing but the coarse shorts or bran proper is fed to horses hereabouts.

In Jamaica Plain, for example, the grain-dealers tell me that they sell as many as five bags of shorts for one bag of fine-feed and middlings. In the country, on the other hand, a great deal of fine-feed, middlings, and mill or ship stuff is fed to milch-cows, and a certain amount of these products is given to swine also. But it is hard to determine in what proportions the materials are employed. Fine-feed is said to be preferred to middlings by many persons, for the purely mechanical reason that it can be mixed more readily than the latter with water or swill. In this immediate vicinity (Jamaica Plain) some fine-feed is bought of the local dealers to be given to growing animals, such as calves, but for milch-cows shorts are sought for. They are said to be used for mixing with brewers' grains, large quantities of which, obtained from the Roxbury breweries, are used by the neighboring farmers. Some of the advantages to be gained by feeding bran-products to cattle in conjunction with straw and inferior grades of hay have been clearly set forth by Mr. E. W. Stewart in the Report of the United States Commissioner of Agriculture for 1865, p. 398.

It is worth noting in this connection that the ash of bran contains an unusually large proportion of phosphates (some fifty odd per cent

of this ash is phosphoric acid, calculated as if it were free and uncombined), and that every ton of shorts or middlings contains from thirty to fifty pounds of ash. All the varieties of bran are consequently well fitted to supply the phosphates needed by milch-cows and by growing animals; and the manure from animals fed with bran will, of course, be specially rich in phosphates. Where bran is used judiciously it can hardly happen that there should be need of feeding out bone-meal to cattle, as is so often done in New England.

I do not wish to be understood as recommending the use of bran in any wholesale or indiscriminate way. Every farmer knows that in beginning to feed an animal with either of the refuse wheat-products the quantity given must be small at first, and must not be increased too rapidly. Perhaps in no event can any very large amount of it be added with advantage to the daily ration. It will always be true of this kind of fodder, that care, attention, and good judgment are necessary in order to its profitable use. There are doubtless many farmers in Massachusetts whose methods of using the material leave nothing to be desired. Their practices should be discovered and held up for imitation. There can be small room for doubting that the use of this kind of fodder in New England ought to be largely increased. The price per ton of bran-feed, no matter whether it be shorts, fine-feed, or middlings, is lower in Boston this winter (1872–73) than that of the ton of hay. It is plain, therefore, that bran is held in comparatively low esteem in this region. No doubt the very fact of its comparatively low price tends to deter some persons from using bran-feed. They would naturally enough argue that, if this material were really valuable, the fact would have been recognized long ago by practical men, and the price forced up by an extended consumption. I am inclined, however, to believe that the low price of bran is in some sense a matter of tradition, and that it is really based upon the old necessity of the miller's having to rid himself of a bulky waste material immediately, constantly, and at any sacrifice.

I am glad to bear witness in this connection to the skill and assiduity which my assistants, Mr. F. P. Pearson and Mr. M. Hutchinson, have exhibited in this investigation and in the ordinary work of the laboratory.

No. 3. — *The Humane Destruction of Animals.* By D. D. Slade, M. D., Professor of Applied Zoölogy.

This essay is intended to give instruction to those who desire to terminate the existence of animals in the most speedy and humane manner, whether such animals are intended for food, or whether they have become useless through age, sickness, or other cause. When we reflect upon the vast number of animals which are put to death in our own country alone, for food, estimated at more than fifty millions every year, not to speak of the thousands that are destroyed for other reasons; and when we bear in mind that a great proportion of these animals are put to death often with the most needless cruelty, simply through ignorance of the proper method of producing speedy death, — it will be readily admitted that an attempt to enlighten the public in this respect may at least serve to diminish the amount of such cruelty, and indirectly lead to other equally satisfactory results. While we write more especially for the farmer, who is from circumstances obliged to slaughter his own animals, and for those who are called upon reluctantly to rid themselves of some fond but disabled pet, we also desire to call the attention of those who pursue the slaughtering of animals as a business to the great necessity of doing their work in the most humane manner possible. To this end, there are certain measures of importance to be kept in view, and to be carried into practice.

Thus, the animal to be slaughtered should be conducted to the spot selected as quietly as possible, without the use of goad or club, and everything calculated to alarm him should be removed. All slaughtering premises should be kept thoroughly cleansed from blood and offal, and no carcasses be allowed to hang in view. No animal should be permitted to witness the death of another. Trifling as these measures may appear to the professional butcher, they are in reality of vast importance, not only in view of avoiding useless cruelty, but as affecting the wholesomeness of meat for food, and the market value of the animal slaughtered; there being no question as to the effects of torture, cruelty, and fear upon the secretions, and if upon the secretions, necessarily upon the flesh.

The slaughtering of animals for food at the present day may be classified under three methods: 1. Rendering the animals insensible by a blow on the head, followed by bleeding; 2. Cutting through or injuring the spinal cord (pithing), so as to destroy the powers of motion and sensation, with subsequent bleeding; 3. Cutting the throat, deeply dividing all the blood-vessels, with or without thrusting the knife into the heart, and without previously stunning the animal. This last method is practised by the Jews in slaying cattle.

From certain experiments conducted for the purpose a few years since in the abattoirs of Paris, it would seem that the first of these methods, namely, that of producing insensibility by some sudden shock to the brain, such as that of a direct and concentrated blow, especially if followed by immediate blood-letting, is attended by less suffering than when death is effected by decapitation, pithing, or cutting the throat without previously producing such insensibility.

A German observer * remarks upon this subject: "All methods of slaughtering have for their object the death of the animal in a more or less speedy, but always in the least painful manner possible. But what is death? and when does actual death occur? Simple as these two questions may appear, they are nevertheless very difficult to answer. A mammal whose head has been cut off by a guillotine does not die immediately. Actual death occurs some seconds or minutes afterwards. All methods of slaughtering other than the one in which insensibility is produced by a severe shock to the brain, followed by bleeding, produce, without exception, only apparent death, after which follows the actual death, the latter being always accompanied with an entire cessation of nervous and muscular excitability."

There are two kinds of motion. The one is voluntary and dependent upon the brain. So long as this organ remains unimpaired, so long will consciousness, sensation, and the power of voluntary motion continue. The other is involuntary, and dependent upon the action of the spinal cord as a nervous centre, and is known as reflex action. This kind of motion is exhibited in the movements of animals after decapitation, where all connection with the brain, and consequently with consciousness, has been cut off.

So intimately connected in our minds are pain and action, that in witnessing the slaughter of two animals we are naturally inclined to

* Dr. Sondermann, of Munich. Our Dumb Animals, Vol. I.

attribute the greatest amount of suffering to the one that at the time of death exhibits the most violent convulsions. In such a conjecture, however, we may be very much mistaken, for it is possible, nay, even probable, that there may be acute suffering with scarcely a struggle on the part of the animal; while, on the other hand, there may be much struggling, and even distortions, without pain or sensations of any kind, as is often made evident in cases of decapitation, where, as we have just remarked, all connection with the brain has been removed.

Thus we see that the movements of an animal in the act of being killed are not at all to be relied upon as evidences of pain.

The term "pithing" is applied to two methods of inflicting injury to the nervous system, and thereby producing death. By one method, that most commonly in vogue, the spinal cord is severed or punctured between the first and second bones of the neck, where the peculiarity of the articulation leaves an opening. This is done by a variety of instruments. Although the animal drops immediately, life continues for some seconds and even minutes, the heart continues to beat, and the brain to live and act. By the other method, a small spot situated in the lower and posterior portion of the brain, known as the "medulla oblongata," is reached and broken up by the introduction of a narrow sharp instrument through the occipital hole. Death is almost instantaneous. "No attempt is made at inspiration, there is no struggle, and no appearance of suffering. The animal dies simply by a want of aeration of the blood, which leads in a few moments to an arrest of the circulation."* Both of these modes of slaughtering, especially the last, require an anatomical knowledge as well as a practical dexterity that but few would attain, and, if they are not properly and quickly executed, are undoubtedly attended by more suffering than other methods.

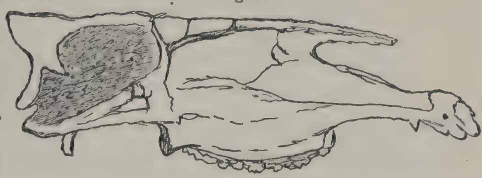
Without entering further into the consideration of physiological questions of so much importance, we may with safety lay down the following proposition: —

All animals, when slaughtered, should be deprived of sensibility by inflicting sufficient injury to the brain, either by a sudden and violent blow of the axe or mallet, by the bullet, or by some other equally efficient means, and should then be immediately bled during the state of insensibility.

* Dalton's Physiology, First Edition, p. 381.

It is important to know the exact situation of the brain in animals, so that the shock to this organ may be conveyed effectually and at once, and not by clumsy and ill-directed efforts, as is too often the case.

Fig. 1.



It should be kept in mind that the brain of animals occupies but a comparatively small portion of the entire head. In the attempt to fell them, the tendency is almost always to strike too low. Fig. 1 represents a longitudinal section of the horse's head, showing the situation of the brain, and also the thinness of the frontal bone *a* as compared with the corresponding region in the ox (Fig. 3).

The horse may be destroyed by blows upon the head, by the bullet, or by chloroform.

1. *By Blows.* — Having led the animal to a suitable spot, blindfolded, and secured him by the halter, the operator, armed with a heavy axe or hammer, should stand upon the left and to the front of the animal, directing his blow to a point in the middle of a line drawn across the forehead from the centre of the pit above the eye. See Fig. 2.

One vigorous and well-directed blow will fell the animal, but the blow should be repeated to make destruction sure. Then, drawing back the head, cut across the throat at its upper portion down to the bone, so as to open freely all the blood-vessels.

Fig. 2.

2. *By the Bullet.* — The operator should stand directly in front of the animal, and place the muzzle of the rifle or pistol within a few inches of the skull, aiming at the spot indicated in Fig. 2.

If the pistol is used, one hand may steady the head by grasping the noseband of the halter, or by taking hold of the forelock. If the rifle is employed, it is better to blindfold the horse or to secure him by the halter. One shot is generally sufficient, if properly directed in either case; if not, it should be repeated after the animal falls.

In most instances, so great and instantaneous is the shock to the brain from a gunshot wound that death follows instantly, and therefore opening the blood-vessels is not required.

The pistol used should carry a large bullet, not smaller than a rifle-ball. A shot-gun loaded with buck-shot is as effectual at a point-blank range, and may often be more conveniently procured.

3. *By Chloroform.* — Procure a common feed-bag or small sack made of thick cotton cloth, or of any sufficiently strong material, provided with strings or a strap to fasten over the head, and at the bottom of this place a large sponge or a yard of flannel folded to the size of eight inches square.

The animal having been led to the spot selected, the sponge or flannel is to be saturated with the chloroform and the bag adjusted. If the suffocation and consequent struggling, which at first attend the administration of anæsthetics, are very great, the application of the chloroform may be gradual, the animal being allowed to respire the outward air for a moment, until these effects pass off. As it is by the exclusion of common air, however, that death is produced, the more persistently the administration of the chloroform is kept up, the more speedy will be the desired result.

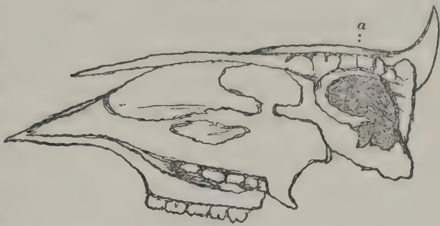
The dose requisite varies very much according to circumstances. At least sixteen ounces of chloroform should be procured, and it should be freshly applied through a small slit in the bag every few minutes until death ensues, which will be from five to ten or fifteen minutes after the beginning of the operation.

The difficulties attending the administration of chloroform to so large and powerful an animal as the horse, particularly at the hands of the inexperienced, render its use less applicable in producing death than either of the other methods. In cases where sickness and consequent debility have reduced the animal and made him less capable of struggling, it answers a good purpose, but, as a general rule, we do not recommend its use where the normal amount of strength still remains.

If the animal to be killed is to be buried without removing the skin, a pit may be dug, large enough for a grave, one end of which should be so excavated as to make an inclined plane, down which the horse can be led. When in the pit, his head is in a convenient position for the axe or the bullet, and when he drops he falls in his grave, and the labor of removing the body is entirely avoided.

The skull of the ox is thicker and heavier than that of the horse, and the brain still smaller in comparison with the entire head. The frontal bone is composed of two plates which are separated by bony ridges forming cells or sinuses. This arrangement (seen in Fig. 3, which represents a longitudinal section of the head) gives to the parts great strength, and forms a secure defence against injuries to the brain, which lies beneath (*a*).

Fig. 3.



Cattle are most readily and conveniently destroyed by blows on the head with a heavy axe or hammer, followed by immediate blood-letting. The animal which is to be killed should be secured by means of a rope passed round the horns and fastened to a post, or, if practicable, carried through a ring in a floor and held by an assistant or made fast. The animal being blindfolded, the operator, armed with a heavy axe or hammer, stands to the left and a little in front of it, and aims his blow at a spot in the middle of a line drawn across the forehead about one inch and a half below the base of the horns, or, perhaps better, at the spot where two diagonal lines intersect, drawn from the eyes to the base of the horns. (Fig. 4.)

In most cases, if the blow is heavy and properly directed, the animal falls instantly; but it is better even then to repeat the blow and to follow it by immediate bleeding. This is accomplished either by drawing back the head, and cutting deeply across the neck at the upper portion of the windpipe, severing all the blood-vessels, or by plunging a long and sharp-pointed knife into the heart and large blood-vessels at a point corresponding to the upper portion of the brisket, and just above the breast-bone.

Fig. 4.

Failure to fell the animal at the first blow cannot be attributed to any difference in the anatomical structure of the part, but rather to the fact that the blow was ill-directed, almost invariably too low, that it was not sufficiently powerful, or that both of these faults were combined.

In the slaughtering of calves, it is not a common practice with us, as it is in France and other countries, to render them insensible before bleeding, for fear that the brain may be made less inviting as an article of food by being torn and stained with blood. By using a broad mallet this may be, in a great measure, avoided, and even if these results do follow, they do not in reality alter the quality of the brain for edible purposes. Objections to the humane destruction of an animal on such grounds are as unreasonable as those which are made to juicy and wholesome red veal by people who prefer that which has been rendered white, dry, and innutritious by repeated bleedings, which have reduced the calf, before death, to a lingering condition of faintness and debility.

The calf should be first stunned by a blow upon the head by a broad mallet or hammer aimed at a spot relatively the same as in the full-grown animal. This is to be followed by immediate bleeding, practised by severing the throat at a point corresponding to the upper portion of the windpipe, using a sharp knife and doing the work thoroughly and at once, so as to open all the arteries and veins of the neck.

Sheep and lambs should be rendered insensible by a blow upon the head, to be followed subsequently by severing the throat, as just advised in the case of calves, or by plunging a sharp-pointed knife through the blood-vessels at either side of the neck between the bones and the windpipe.

The place to be selected for a blow is the centre of a line drawn across the head about two inches above the eyes, the brain in the sheep occupying a situation posterior to what at first sight would appear to be the natural one.

There is an idea prevalent among farmers, and even among many of those who practise the slaughtering of swine as an avocation, that, if these animals are first rendered insensible by blows upon the head, it is impossible to empty the blood-vessels.

There is no foundation, however, for any such opinion. Any obstacles to bleeding are due, not to material differences in the anatomical arrangement of the blood-vessels, but solely to the difficulties attending the cutting through of the great mass of fat and flesh which characterizes the necks of swine in order to reach these vessels.

This very difficulty is a reason why the animal should be rendered insensible before bleeding, not only on the score of humanity, but also on the score of avoiding the barbarous sights and sounds which so frequently disgrace our towns and villages.

In Europe generally, and at the present time in our large slaughtering establishments, both in New England and at the West, the swine are always first rendered insensible by being stunned. They should be made insensible by a blow upon the head, directed, not between the eyes, but upon a spot in the middle of a line drawn across the head three to four inches above the eyes. A long sharp knife should then be thrust deeply through the lower portion of the brisket, at a point just above the breast-bone, severing the large vessels leading from the heart. To facilitate this operation, the head should be drawn back by the hand holding the snout. The point of the knife after it has been thrust in should be swept about and made to cut more extensively in the deep parts than at the surface. This insures the thorough division of the blood-vessels and the most rapid and effectual bleeding of the animal.

Small dogs, cats, and other diminutive animals, particularly if sick or in any way disabled, are humanely destroyed by means of chloroform.

This substance should be administered by pouring from half an ounce to an ounce of it on to a sponge or folded flannel, placed within a thick cloth or towel, and applied over the mouth and nostrils. If the struggling is severe at first, the administration of the chloroform may be made more gradual by removing the sponge or flannel, for a moment, altogether, and then reapplying it ; and, as the animal becomes quiet, it should be kept on closely and constantly, to the entire exclusion of the outward air, adding fresh chloroform from time to time until death occurs. The length of the operation will depend upon the size and condition of the animal, and the persistence with which the administration has been kept up.

As a protection against the struggles of the animal to free itself, the body may be placed in a sack or bag, allowing the head to protrude. Or a blanket may be thrown over the body, by which it may be grasped, while the head is left free for the application of the sponge. Or the animal, together with the saturated sponge, may be placed in a small box and allowed to go quietly to rest.

The young of cats and dogs, when but a few days or hours old, may be humanely destroyed by drowning, if properly executed. This can be best accomplished by placing them in a tight bag containing a stone of sufficient weight to insure speedy sinking.

The quickest method of terminating the existence of a large dog is, undoubtedly, to shoot him. To do this properly and effectually, it is far preferable to use a pistol, and to place the muzzle of it within a few inches of the head, at the side, just over and in front of the ear. If the rifle is used, the same spot should be aimed at.

It is a common practice to shoot a dog with a pistol, the muzzle of which is directed behind the ear. In this case, unless exactly aimed in the right direction, the ball is likely to glance and pass through the soft parts of the neck, and although death might be the result of the shot, it would neither be so certain nor so instantaneous as if the brain had been pierced.

In the attempt to destroy it, no animal should be merely maimed. For this reason, if a gun or fowling-piece should be used, it should be charged with buck-shot, the side of the head aimed at, and sufficiently near to insure speedy death.

The same remarks apply to the destruction of cats. As this animal is smaller, however, death may be instantly effected by small shot fired from a gun at the head, sufficiently near to prevent the scattering of the charge.

The remarks which we have already made as regards producing insensibility by a blow upon the brain may equally apply to poultry. The almost universal method of killing by chopping off the head of a fowl, and allowing the body to flutter about upon the ground, is not an agreeable sight, and has certainly a demoralizing effect upon those who witness it, especially upon the young and those who are not yet callous to such sights. The same may be said also of the practice of opening the blood-vessels in the necks of poultry, and allowing them to bleed to death more or less slowly. Therefore, to produce insensibility, make use of either of the following modes.

1. Grasp the bird by the legs, place its head upon a block, and strike it a smart, quick blow with a small club, or with some equally efficient weapon, and then immediately sever the head from the body by a sharp cleaver or hatchet. Retain the body in the hand until all fluttering has ceased.

2. Taking the bird up, compress the throat between the thumb and finger for a minute. Retaining the grasp, swing the body round several times, and then remove the head as just described. Here insensibility is produced by suffocation and loss of motion by the twisting of the bones of the neck.

3. A very sharp blow, with a small but heavy stick, behind the neck, at about the second joint from the head, will injure the spinal cord so as to destroy sensation and motion, if properly executed; the head to be afterwards severed from the neck.

4. Hang up the bird by the legs, and thrust a long, narrow, sharp-pointed knife, like a penknife, into the brain through the back part of the roof of the mouth. Death is instantaneous. To do this considerable dexterity is required.

It has been observed that fish which are instantly killed on being taken from the water are vastly superior, in taste and solidity, to those which are allowed to die, as is the universal custom with us. And why should this not be the case? Why should we make a distinction in this respect between animals that swim and those that fly or run? No one of us would think of eating beast or bird that had died a natural death. Various modes of killing fish are practised by different people. The Dutch, for example, destroy life by making a slight longitudinal incision under the tail by means of a very sharp instrument.

On the Rhine they kill the salmon by thrusting a steel needle into their heads.

Fish may be easily destroyed by striking them a quick, sharp blow with a small stick on the back of the head just behind the eyes, or by taking them by the tail and striking the head quickly against any hard substance.

We have made no remarks upon the destruction of animal life by means of deadly poisons, as such agents cannot, with safety, be placed in the hands of the unskilled. Neither have we spoken of the use of various gases as a means of humane destruction, such means not being at the disposal of the people generally.

No. 4. — *On the Agricultural Value of the Ashes of Anthracite.*

By F. H. Storer, Professor of Agricultural Chemistry.

The question "whether the ashes of hard coal have any fertilizing power" has often been debated in New England.

It is a not unnatural assumption that coal-ashes should have some value as manure, in view of their analogy with wood-ashes, and of the current belief that coal has been derived, if not from wood, at least from plants of some kind. But coal is a substance that has undergone many changes, and we have to consider, not only what proportion of the potash and phosphoric acid originally contained in the coal-producing vegetation has been left in the coal, but how much of the potash and phosphoric acid in a coal is left in the ash of that coal in a condition fit for the use of growing plants. In other words, we must inquire how much of the original potash and phosphoric acid have been washed out by water while the coal was being formed, or have been locked up and compounded by the action of heat, — either the heat to which the coal may have been subjected while forming, or that which it must necessarily undergo when burned.

Several attempts to answer the main question, in part at least, have been made by way of analyzing the coal-ashes.* But in the present imperfect condition of chemical art we can hardly hope to determine by analysis alone what portion of the potash and phosphoric acid actually found in coal-ashes is fit and ready to serve as plant-food. On the other hand, very many farmers and gardeners have tried to estimate the value of coal-ash by noting its action upon crops in actual field practice, and it is with regard to the results of these tests that discussions have arisen in our agricultural societies. In point of fact, it is not easy to come to any very nice or very definite conclusion in this way; the experiment is necessarily complicated by bringing the ashes into the presence of a great variety of substances, — both those natural to the soil and those which have been added to it by previous manuring, — and unless the ashes possessed decided and well-marked fertilizing power it might often happen that they could not exhibit

* See, for example, Bunce, "Wells's Annual Scientific Discovery," 1851, p. 305; Horsford, "Proceedings American Scientific Association," 1849, p. 233.

their true worth in the face of these disturbing influences. It is probable, moreover, that the materials thus tested really differed widely among themselves as regards the amount of wood-ashes contained in them. It is well known that a large proportion, if not most, of the coal-ash obtained from domestic fires is mixed with more or less wood-ashes, derived from the kindling materials or from wood used in conjunction with the coal. It often happens, indeed, that the proportion of wood-ashes is so large that the mixture has from that cause decided value as a fertilizer.

In consequence of this lack of purity, so to speak, of the ashes used, many of the field experiments which have been made hitherto have had little or no bearing upon the question as to the value of coal-ashes. Such tests have been useful, no doubt, in so far as they gave information concerning the ashes of the particular house or fire whence they were procured, but they lack general significance. There can be no doubt, however, but that the field experiments, taken all together, have proved pretty conclusively that coal-ashes, when free from wood-ashes, have no great fertilizing power. And, in fact, there seems to prevail among the farmers of New England a very generally diffused, though perhaps a not very firm or well-defined belief, that coal-ashes, by themselves, have no agricultural value whatever, excepting in so far as they may be made to serve as well as an equal quantity of sand or gravel for the mechanical improvement of low-lying peaty soils.

In the hope of gaining some definite knowledge which might serve to settle the question, I have subjected coal-ashes to still another method of investigation; to the method, namely, of growing plants in a considerable number of pots of ashes treated in such wise that in each pot the ashes might supply to the plant, if they could, some one or more of the ingredients needed for its growth. The ashes employed in these experiments came from the burning of hard white-ash anthracite coal from Pennsylvania in two of the furnaces used for heating the stone building of the Bussey Institution. Care was taken so to manage the fires that no wood-ashes could by any possibility become mixed with the ash of the coal. The ashes were sifted through a sieve carrying four meshes to the inch, and were kept protected from dust and fumes. The experiments were conducted in the glass-house, or conservatory, which constitutes one room in the Bussey Laboratory.

Several sets of experiments have been tried. Those of the first set (designated Series A) were made in the spring of 1872 with ashes from a furnace in which they had been exposed to a comparatively high temperature. The purpose of this first series of experiments was to find a plant well fitted to support at one and the same time the hardships of living in a glass-house and of growing in a very poor soil.

A number of clean earthen flower-pots were charged with various sands and soils, — among other things, with five hundred grammes of the coal-ashes to the pot, — and planted with seeds of oats, barley, beans, clover, maize, buckwheat, turnips, etc. Each pot was watered freely with rain-water, poured into its saucer, during three months, and the condition of the plants was noted from week to week. None of the plants really prospered in the coal-ashes. The beans and peas grew to a considerable height, it is true, but it was plain that the matter of which the new parts of these plants were formed came chiefly from the older parts. The nitrogen, at all events, needed for the formation of new leaves and stems, was apparently the same that had taken part in the formation of the first shoots and leaves derived from the seed. This continued growth by instalments, based upon the original stock of substance in the seed, was well marked in the case of nasturtiums also. Some other plants derived from large seeds, such as lupins and maize, shot up to a noticeable height by help of the store of nourishment in the seeds planted. But out of seventeen kinds of seeds sown, no single crop came to maturity.

The general result of the trials was to indicate that buckwheat is a plant well suited for this kind of experiment.

A special experiment, tried simultaneously with the foregoing, gave a very striking result, as follows: On March 18, 1872, ten barley-corns were put to soak in water for twenty-four hours, and were subsequently made to germinate in a porous earthen dish kept covered and moist. All the seeds germinated successfully, in spite of weather cold enough to occasionally freeze the water in and about the dish that contained them. On April 2 the sprouted seeds were planted in coal-ashes, in an earthen pot five inches in height and diameter; the pot was placed in the glass-house and gradually brought into sunlight, so that on April 9 it was in position beside the other pots. During the following week the barley-plants grew tolerably well, but, like all the rest, they soon began to languish, and when about four

inches high remained wellnigh stationary; what little growth there was at the top being for the most part supported by the transfer of matter originally contained in the lower leaves. On April 30, when the plants in this crowded pot were white and almost completely dead, a dilute solution of nitrate of lime was substituted for the rain-water which the plant had previously received, and this special pot was thenceforth watered solely with the nitrate solution. All but two of the dying plants slowly recovered under this treatment. In a fortnight they had become thrifty, in three weeks' time they were vigorous, and by the end of May they exhibited a luxuriant growth.

Eight plants were harvested in August, each two feet tall and bear ing good-sized ears filled with mature grain. The weight of the crop dried at 100° C. was 13.778 grammes.*

By analysis, these plants were found to contain, grain and straw together, 7.98 per cent of ashes, and the ashes contained, —

24.09	per cent of	silica,
10.67	"	lime,
5.41	"	magnesia,
1.12	"	potash,
4.08	"	phosphoric acid,
1.44	"	sulphuric acid,

besides other things not determined.

A somewhat similar experiment was tried with the five oat-plants of Series A, and, although the plants had been left to starve until their lower portions had become so hard and callous, before the attempt to save them was made, that they were almost useless, three of the plants slowly revived under the influence of a dilute solution of nitrate of soda, and finally came to maturity. Soon after the nitrate began to be used the white stalks and leaves of the oat-plants became green, and when harvested the plants were seventeen inches high, and each of them bore five or six seeds.

These preliminary trials indicated very clearly that, whatever else the coal-ashes under examination might lack, the first thing to be added to them was a supply of nitrogen. Hence the following series

* The five barley-plants of Series A, grown in coal-ashes at the same time as the above, in a similar earthen pot, and under like conditions, excepting that they were watered with rain-water alone, yielded only 0.4051 grammes of total crop, dried at 100°.

of experiments (B), which were made in the autumn of 1872, upon ashes of the same quality as those used in A. Eleven wide-mouthed glass jars (preserve-jars) were each charged with 525 grammes of the coal-ashes. Three buckwheat seeds were planted October 28 in each jar, and all the jars were watered with rain-water until the seeds had germinated and the young plants had begun to grow independently of the seed. Thenceforth each jar, excepting one that got nothing but rain-water, was watered either with a very weak solution of nitrate of potash,* nitrate of lime,† nitrate of ammonia,* sulphate of magnesia,* or phosphate of potash,* or with a mixture of two or more of these solutions.

The result of these trials will appear from the following table: —

No. of jar.	The ashes were watered with	The crop (harvested Jan. 2, 1873). Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Had seeds.	Remarks.
1	Nitrate of potash .	0.665	2 plants = 13 1 " = 11½	23	
2	Sulphate of magnesia	0.095	1 " = 7½ 1 " = 7 1 " = 4½	3	
3	Nitrate of lime . .	1.360	1 " = 14 1 " = 13½ 1 " = 11	23	
4	Nitrate of potash and sulphate of magnesia	0.720	2 " = 13½ 1 " = 9	21	
5	Rain-water . . .	0.090	1 " = 7½ 1 " = 6½	2	There were only two plants.
6	Nitrate of ammonia .	0.840	1 " = 12½ 1 " = 12	22	Only two plants.
7	Phosphate of potash	0.135	2 " = 7 1 " = 6	4	
8	Nitrate of lime and phosphate of potash	1.365	1 " = 13 1 " = 12½ 1 " = 11	37	
9	Sulphate of magnesia and phosphate of potash .	0.105	1 " = 7½ 1 " = 6½	2	Only two plants.
10	Nitrate of lime, sulphate of magnesia, phosphate of potash	1.040	1 " = 16 2 " = 9½	38	
11	Nitrate of lime, nitrate of potash, sulphate of magnesia, phosphate of potash	1.050	1 " = 18 1 " = 14 1 " = 7	25	

* 0.25 gramme to the litre. † 1.00 gramme to the litre.

The weight of the three buckwheat seeds planted, as deduced from the mean of a number of weighings, was a little more than 0.06 gramme.

If, for the sake of comparison, we call the weight of the crop obtained from the ashes by water alone = 1, then the weight of the other crops will be respectively as follows :—

No. of the jar.	Chemicals employed.	Comparative yield of dry substance; the crop by water alone = 1.
8	Nitrate of lime and phosphate of potash . . .	15.16
3	Nitrate of lime	15.00
11	Nitrate of lime, nitrate of potash, sulphate of magnesia, and phosphate of potash	11.66
10	Nitrate of lime, sulphate of magnesia, and phosphate of potash	11.55
6	Nitrate of ammonia	9.33
4	Nitrate of potash and sulphate of magnesia . .	8.00
1	Nitrate of potash	7.17
7	Phosphate of potash	1.50
9	Sulphate of magnesia and phosphate of potash .	1.17
2	Sulphate of magnesia	1.06
5	Rain-water	1.00

Experiments like these are almost inevitably exposed to a variety of accidents, such as the failure of some seeds to germinate, and the occasional death of a young plant at the critical moment when support from the seed ceases and the plant is thrown upon its own resources.

In general, results obtained in this way must be looked upon as approximations to the truth, rather than as absolutely correct. But several of the results above tabulated are very striking. It is plain that the ashes used must have contained appreciable quantities of potash and phosphoric acid, as well, of course, as the lime, magnesia, sulphuric acid, and iron which are necessary for the growth of plants ; for on the addition of nitrogenized salts to the ashes abundant crops of buckwheat and of barley could be readily grown. The action of the nitrates is well marked, and beneficial, in every instance. The solution of nitrate of lime, which was much richer in nitrogen than either of the others, gave a crop twice as large as that yielded by nitrate of potash, and the jar watered with nitrate of ammonia, though containing only two plants, produced more than that watered with nitrate of potash, — apparently because it received a larger quantity of nitrogen. The addition of potash and phosphoric acid, as in jar No. 8, did little or no good, while sulphate of magnesia seemed to do harm.

It remained to be seen whether the ashes were any better in respect

to potash and phosphoric acid than ordinary sand. In the hope of throwing some light upon this point, a series of experiments (C, planted December 9, 1872) was undertaken, precisely similar to those in Series B, with the exception that the 525 grammes of ashes were replaced by 1,000 grammes of pit-sand taken from an excavation in the field next adjoining the Plain-field of the Bussey Institution. This pit-sand constituted a bed or layer two or three feet thick in the coarse drift, granitic (?) gravel of the locality, and was situated about three feet below the surface of the ground. The sand was dug out by itself, apart from the gravel, to be sold for making mortar. It was a clean, gritty, yellow sand, composed mainly of quartz, and seemed at the first glance to be sufficiently ill-adapted for the support of growing plants, though on closer inspection fragments of several kinds of rocks could be seen everywhere interspersed among the silicious particles. The sand was placed in the jars in the condition in which it was obtained at the pit. It was not washed or purified in any way.

The results of these experiments are set forth in the following table : —

No. of jar.	The pit-sand was watered with	The crop (harvested March 4, 1873).			
		Weighed in grammes (dried at 90 to 100 degrees C.).	Grew to height in inches.	Had seeds.	Remarks.
1	Nitrate of potash .	1.410	15	27	
2	Sulphate of magnesia	0.360	13	7	Only two plants.
3	Nitrate of lime . . .	1.600	14	16	
4	Nitrate of potash and sulphate of magnesia	1.485	14	22	
5	Rain-water	0.065	best = 8	2½	
6	Nitrate of ammonia	1.075	15	13	
7	Phosphate of potash	0.325	13	3½	
8	Nitrate of lime and phosphate of potash	1.715	best = 20	29	
9	Sulphate of magnesia and phosphate of potash	0.145	9	2	
10	Nitrate of lime, sulphate of magnesia, and phosphate of potash	1.980	17	29	
11	Nitrate of lime, nitrate of potash, sulphate of magnesia, phosphate of potash	1.760	17	29	

If, as before, we refer the weights of the several crops to the weight of that with water as unity, the results will stand as follows : —

No. of the jar.	Chemicals added to the pit-sand.	Comparative yield of dry substance; the crop by water alone = 1.
10	Nitrate of lime, sulphate of magnesia, and phosphate of potash	30.46
11	Nitrate of lime, nitrate of potash, sulphate of magnesia, phosphate of potash	27.01
8	Nitrate of lime and phosphate of potash	26.38
3	Nitrate of lime	24.62
4	Nitrate of potash and sulphate of magnesia	22.85
1	Nitrate of potash	21.64
6	Nitrate of ammonia	16.53
2	Sulphate of magnesia	5.54
7	Phosphate of potash	5.00
9	Sulphate of magnesia and phosphate of potash	2.23
5	Rain-water	1.00

These results were somewhat unexpected. They indicate clearly that the thousand grammes of sand gave up to the plants more potash and phosphoric acid than the five hundred and twenty-five grammes of coal-ashes did ; though we are left in some doubt as to whether the sand is absolutely superior to the ashes, weight for weight. It may be that the better effect produced by the sand, as compared with the ashes, is due to the fact that a larger amount of it was employed. It is true, moreover, that the comparatively coarse and incoherent sand affords better standing-room for plants than ashes can. The tender rootlets push their way through the sand in all directions more readily than is possible in the comparatively compact ashes.

It is plain, however, from the foregoing trials, that no *general* answer can be made to the question whether coal-ashes possess more fertilizing power than sand. For, inasmuch as the experiments prove that the coal-ashes examined were no better than a sample of pit-sand, of nearly equal bulk, selected at random, the question as to the relative merit of ashes and sand necessarily becomes a special one, which must be asked afresh for the sand of each new locality, and which can be answered only by experiments made upon each particular sand. The fact remains, however, no less interesting than remarkable, that an average sample of the apparently sterile silicious sand of this vicinity has been found to contain appreciable quantities of potash and phosphoric acid in a condition fit to be taken up by plants on the addition

of nitrogenized compounds. This fact explains at once the power of bearing trees which is possessed by much of the sandy and gravelly "drift" of Eastern Massachusetts. As is well known, many of our drift hills and ridges have been devoted to the growth of hardwood incessantly for a very long period. Every twenty or thirty years the trees are cut down, and, the sprouts which spring from their stumps being suffered to grow, a new crop of firewood is found ready for the axe at the end of another term of twenty or thirty years. This practice of continually growing and carrying off a single crop without respite, manure, or rotation has already been adduced by Professor Johnson as an excellent illustration of what farmers call working on the natural strength of the land. But the experiments of Series C go to show that in some instances at least, and probably in most, where trees flourish upon drift, the elements of strength are contained in the very sand itself. So long as there is a deposit of humus on the surface of the land to supply the necessary nitrogen, there is no need of supposing that much of the food consumed by the trees must be brought to them from afar by the soil-water, for, as has just been shown, the sand in which the trees stand may be competent to supply potash, phosphoric acid, and the other ash ingredients.

The experiment enforces the lesson that glacier sand (such as composes the New England drift) is ordinarily a very different thing from the sea-sand of the dunes upon the Atlantic coast. It is plain, for that matter, that a quantity of crushed rocks and minerals slowly undergoing decomposition and disintegration, through the agency of fresh water and the matters held in solution by such water, in heaps or hills such as glacial action has thrown up all over the Northern United States, must usually contain a much larger proportion of plant food than sand that has been formed upon sea-beaches from the same kinds of rocks. From the sand that forms the dunes almost everything but silica has doubtless been removed through long-continued grinding of the rocky materials upon the beach in a saline solution that was continually changed and renewed.

Another series (D) of experiments was next undertaken in order to compare the pit-sand with coal-ashes under precisely similar conditions as to the time and season in which the crops grew, and also to compare the ashes and pit-sand both with a very poor sand and a very fertile one. Four sets of glass jars, each set containing sixteen

jars, were charged as follows: The first set with 525 grammes of ashes from hard white-ash anthracite coal from Pennsylvania. This coal was taken from a different lot from that which furnished the ashes used in the experiments of Series A and B. It was burned, moreover, in a much shallower furnace, and one surrounded upon all sides by a "water-back" or jacket through which water continually circulated, so that much of the ashes may never have been subjected to so high a temperature as that to which the greater part of the ashes used in Series A and B were inevitably exposed. Some portions of these ashes from the shallow furnace, and many of the fragments of unburnt coal which were mixed with them, undoubtedly came through the grate bars without ever having been even strongly heated.

The second set of jars received 1,370 grammes of pit-sand similar to that used in Series C. The third set was charged with 1,350 grammes of the pure white quartz sand of Berkshire County, in this State, such as is used at the flint-glass works of this vicinity. The fourth set was filled with 1,210 grammes of "West Jersey Green Sand Marl" from New Jersey.

Three buckwheat seeds were planted in each jar on the 11th of January, 1873, and in due course the jars were watered with weak solutions of various chemicals, applied either singly or admixed, as in Series B and C. The kinds and strengths of these solutions will appear from the following list.

Sulphate of magnesia, sulphate of lime, chloride of potassium, and phosphate of potash, each 0.25 gramme to the litre.

Nitrate of lime 1 gramme to the litre, nitrate of potash 1.25 gramme to the litre, and nitrate of ammonia 0.5 gramme to the litre. The three nitrogenized solutions were made of such strength that a litre of each of them contained as much nitrogen as was contained in a litre of the nitrate of lime solution employed in Series B and C. The results of these experiments are given in the following tables: —

SERIES D. SET 1. COAL-ASHES.

No. of jar.	The ashes were watered with	The crop (harvested March 14, 1873). Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Had seeds.	Remarks.
1	Sulphate of magnesia	1.010	1 plant = 15 1 " = 14	21	Only two plants.
2	Sulphate of lime .	1.360	1 " = 14 1 " = 12 1 " = 10	19	Besides flowers.
3	Chloride of potassium	0.360	1 " = 9	6	Only one plant.
4	Phosphate of potash	1.170	1 " = 16 1 " = 12 1 " = 10	34	
5	Nitrate of potash .	1.950	1 " = 15 2 " = 14	34	
6	Nitrate of lime . .	1.800	1 " = 15 2 " = 14	28	Several flowers.
7	Nitrate of ammonia	0.920	1 " = 13 1 " = 10	9	Only two plants.
8	Rain-water . . .	1.160	1 " = 15 2 " = 11	19	
9	Nitrate of potash and phosphate of potash	2.200	1 " = 20 1 " = 16 1 " = 11	18	Many flowers.
10	Nitrate of lime and phosphate of potash	1.265	2 " = 14	16	Only two plants. Many flowers.
11	Nitrate of potash and sulphate of magnesia	1.400	1 " = 17 1 " = 16 1 " = 13	22	
12	Phosphate of potash and sulphate of lime	1.325	2 " = 13 1 " = 12	5	Many flowers.
13	Phosphate of potash and sulphate of magnesia	1.370	1 " = 13 1 " = 12	27	Many flowers. Only two plants.
14	Nitrate of lime, phosphate of potash, sulphate of magnesia	2.165	1 " = 17 2 " = 16	35	Several flowers.
15	Nitrate of lime, phosphate of potash, sulphate of lime .	1.635	2 " = 16	8	Few flowers. Only two plants.
16	Nitrate of lime, chloride of potassium, phosphate of potash, sulphate of magnesia	2.580	1 " = 16 1 " = 15 1 " = 10	26	Many flowers.

SERIES D. SET 2. PIT-SAND.

No. of jar.	The pit-sand was watered with	The crop (harvested March 14, 1873).			
		Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Had seeds.	Remarks.
1	Sulphate of magnesia	0.130	1 plant = 9 2 " = 7	4	
2	Sulphate of lime .	0.100	1 " = 9 1 " = 7 1 " = 5	2	
3	Chloride of potassium	0.115	1 " = 8 2 " = 7	4	
4	Phosphate of potash	0.090	2 " = 8 1 " = 6	4	
5	Nitrate of potash .	2.620	1 " = 19 1 " = 17 1 " = 15	51	
6	Nitrate of lime . .	2.510	1 " = 21 1 " = 19 1 " = 18	70	
7	Nitrate of ammonia	2.190	1 " = 19 1 " = 18 1 " = 17	43	
8	Rain-water . . .	0.120	2 " = 9 1 " = 8	4½	
9	Nitrate of potash and phosphate of potash	2.430	1 " = 22 1 " = 18 1 " = 15	40	A few flowers.
10	Nitrate of lime and phosphate of potash	2.430	1 " = 20 2 " = 17	46	
11	Nitrate of potash and sulphate of magnesia	2.900	1 " = 19 2 " = 15	41	
12	Phosphate of potash and sulphate of lime	0.170	3 " = 8	2	
13	Phosphate of potash and sulphate of magnesia	0.070	2 " = 7	1	Only two plants.
14	Nitrate of lime, phosphate of potash, sulphate of magnesia	3.005	1 " = 19 2 " = 14	43	
15	Nitrate of lime, phosphate of potash, sulphate of lime	2.965	1 " = 24 1 " = 17 1 " = 16	65	
16	Nitrate of lime, chloride of potassium, phosphate of potash, sulphate of magnesia	2.665	1 " = 17 2 " = 16	39	

In comparing the results of these trials with those obtained in Series C, it is to be observed that the plants in Series D (planted January 11) were exposed, not only to more daylight than those planted a month earlier, but, as it happened, to much more sunlight. Their life was more vigorous than that of the plants in Series C. Owing to the inevitable variations of the seasons, it is important that experiments of this sort should be made side by side, in order that the results obtained may be strictly comparable.

The nitrogenized solutions employed in Series D were stronger than those used in the preceding series, excepting only the solution of nitrate of lime. Due allowance must be made in several instances where one or more of the seeds planted failed to grow. As has been stated already, the coal-ashes of Series D were obtained from a different furnace from the one that supplied the ashes of Series A and B, and from another lot of coal. It is plain from the results tabulated above, as it was from the appearance of the plants during their growth, that the ashes of Series D contained, or in some way supplied to the plants, a small proportion of nitrogen.* So good a crop was obtained from these ashes by the use of rain-water alone, as well as by the use of rain-water containing matters which had been found by the experiments of Series A, B, and C to be useless in the absence of nitrogen, that the best crops in this set of ash experiments seem small by comparison. Yet the absolute weight of the crop watered with nitrate of lime, for instance, is greater in Series D than in Series B.

* I am at present unable to explain the occurrence of nitrogen in this connection. No compound of cyanogen, of ammonium, or of nitric acid could be detected in the ashes. The rain-water of course contained the trace of nitrate of ammonia proper to it. But how little importance is to be attached to that source of nitrogen may be seen by inspecting the results of the experiments upon pit-sand and Berkshire sand as well as the previous set of experiments (Series B) with ashes. It is conceivable, perhaps, though hardly probable, that the nitrogen of torrefied anthracite, like that of roasted leather, may be available for plants. The matter needs investigation.

SERIES D. SET 3. BERKSHIRE SAND.

No. of jar.	The Berkshire sand was watered with	The crop (harvested March 14, 1873). Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Had seeds.	Remarks.
1	Sulphate of magnesia	0.100	1 plant = 6 1 " = 4 1 " = 3	3	
2	Sulphate of lime . .	0.140	2 " = 6 1 " = 4	3	
3	Chloride of potassium	0.090	1 " = 7 1 " = 6	2	Only two plants.
4	Phosphate of potash	0.075	1 " = 5 1 " = 4 1 " = 3	0	
5	Nitrate of potash . .	0.295	2 " = 11 1 " = 9	4	
6	Nitrate of lime . .	0.420	1 " = 11 1 " = 10 1 " = 7	3	
7	Nitrate of ammonia .	0.370	2 " = 10 1 " = 9	6½	
8	Rain-water . . .	0.100	1 " = 7 2 " = 5	2½	Plants yellow and unhealthy, disposed to drop leaves while still succulent.
9	Nitrate of potash and phosphate of potash	0.635	3 " = 10	7	
10	Nitrate of lime and phosphate of potash	2.290	1 " = 16 2 " = 14	14	
11	Nitrate of potash and sulphate of magnesia	0.200	1 " = 9 1 " = 8	4	Only two plants.
12	Sulphate of lime, phosphate of potash	0.115	1 " = 7 1 " = 5	1	Only two plants.
13	Phosphate of potash, sulphate of magnesia	0.145	1 " = 7 1 " = 5 1 " = 4	1	
14	Nitrate of lime, phosphate of potash, sulphate of magnesia	2.185	1 " = 16 2 " = 14	37	
15	Nitrate of lime, phosphate of potash, sulphate of lime .	1.935	1 " = 16 2 " = 14	25	
16	Nitrate of lime, chloride of potassium, phosphate of potash, sulphate of magnesia	2.195	1 " = 19 1 " = 18 1 " = 15	24	Some flowers.

The foregoing set of experiments shows very clearly how plants are affected by the several solutions when applied to a really sterile sand.

SERIES D. SET 4. NEW JERSEY GREEN SAND.

No. of jar.	The green sand was watered with	The crop (harvested March 14, 1873). Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Had seeds.	Remarks.
1	Sulphate of magnesia	0.170	1 plant = 8 2 " = 7	3	
2	Sulphate of lime . .	0.090	1 " = 7 1 " = 6	1	Only two plants.
3	Chloride of potassium	0.100	1 " = 8 1 " = 6 1 " = 5	2	
4	Phosphate of potash	0.085	1 " = 6 1 " = 5 1 " = 4	?	
5	Nitrate of potash .	3.520	1 " = 18 1 " = 16 1 " = 15	22	Very rank growth.
6	Nitrate of lime . .	3.080	3 " = 17	50	
7	Nitrate of ammonia	1.690	1 " = 14 2 " = 13	31	
8	Rain-water . . .	0.120	1 " = 9 1 " = 8 1 " = 5	3	
9	Nitrate of potash and phosphate of potash	3.060	1 " = 18 1 " = 17 1 " = 14	26	Some blossoms.
10	Nitrate of lime, phosphate of potash	2.540	1 " = 18 1 " = 16 1 " = 14	54	Some blossoms.
11	Nitrate of potash, sulphate of magnesia	2.530	1 " = 19 2 " = 16	17	Some blossoms.
12	Phosphate of potash, sulphate of lime .	0.095	2 " = 8	2	Only two plants.
13	Phosphate of potash, sulphate of magnesia	0.065	1 " = 7 1 " = 5	?	Only two plants.
14	Nitrate of lime, phosphate of potash, sulphate of magnesia	2.365	3 " = 14	39	
15	Nitrate of lime, phosphate of potash, sulphate of lime .	2.640	1 " = 16 1 " = 14 1 " = 10	12	A few blossoms.
16	Nitrate of lime, chloride of potassium, sulphate of magnesia, phosphate of potash	1.450	1 " = 13 1 " = 11	7	Many blossoms. Only two plants.

It will be seen at a glance that the various nitrates taken by themselves are here of very little use. Even the mixture of nitrate of potash and phosphate of potash in jar No. 9 fails from lack of lime. But the mixed solutions which contain all the elements needed for the growth of plants yield as good crops in the sterile sand as in the comparatively speaking fertile sand of the other sets of experiments.

The last set of experiments, Series D, Set 4, illustrates very clearly the fertilizing power of the New Jersey green sand, both as regards potash and phosphoric acid, as well as the importance of using a nitrogenized manure in conjunction with the green sand in order that the latter may produce its proper effect in actual field-practice. It is interesting to note in all the experiments how readily the comparatively speaking insoluble "rock-phosphates" of the sands are put to use by plants that are duly supplied with potash and nitrogen and the other kinds of plant-food, *provided the soil is kept moist.*

In the following table the results of the four sets of experiments of

No. of jar.	Chemicals employed.	Comparative yield of dry substance; the crop from Berkshire sand and water = 1.			
		Ashes (containing some nitrogen).	Pit-sand.	Berkshire sand.	New Jersey green sand.
1	Sulphate of magnesia . . .	10.10	1.30	1.00	1.70
2	Sulphate of lime	13.60	1.00	1.40	0.90
3	Chloride of potassium . . .	3.60	1.15	0.90	1.00
4	Phosphate of potash . . .	11.70	0.90	0.75	0.85
5	Nitrate of potash	19.50	26.20	2.95	35.20
6	Nitrate of lime	18.00	25.10	4.20	30.80
7	Nitrate of ammonia . . .	9.20*	21.90	3.70	16.90
8	Rain-water	11.60	1.20	1.00	1.20
9	Nitrate of potash and phosphate of potash	22.00	24.30	6.35	30.60
10	Nitrate of lime and phosphate of potash	12.65*	24.30	22.90	25.40
11	Nitrate of potash, sulphate of magnesia	14.00	29.00	2.00*	25.30
12	Phosphate of potash and sulphate of lime	13.25	1.70	1.15	0.95*
13	Phosphate of potash and sulphate of magnesia . . .	13.70	0.70*	1.45	0.65*
14	Nitrate of lime, phosphate of potash, sulphate of magnesia	21.65	30.05	21.85	23.65
15	Nitrate of lime, phosphate of potash, sulphate of lime . .	16.35	29.65	19.35	26.40
16	Nitrate of lime, chloride of potassium, sulphate of magnesia, phosphate of potash .	25.80	26.65	21.95	14.50*

* Only two plants.

Series D are compared with one another, the weight of the crop obtained from the sterile Berkshire sand by the use of rain-water alone being taken as unity.

A somewhat more satisfactory comparison between coal-ashes and pit-sand could probably be made by repeating the experiments in jars of unlike sizes, filled with equal weights of the two materials, though from the dissimilarity of their mechanical condition and texture it would not be easy to have all the conditions of the experiment precisely similar in the two cases. No such trial has been made, for the reason that enough seems to have been done already to exhibit the two substances in their true relations. It has been proved, at all events, that although the ashes of the Pennsylvania white-ash coal examined do contain appreciable quantities of potash and phosphoric acid in a condition fit for the support of plants, they are, nevertheless, inferior in this respect to an equal bulk of a good pit-sand from Eastern Massachusetts. As regards the question whether sand or coal-ashes is best fitted for the amelioration of low lands rich in humus, it appears that it must come up afresh in every new locality; it can hardly be answered at present except by means of experiments made upon each particular sand.

It is true, as will be shown further on, where some results obtained by analyzing the two substances are contrasted, that the smaller weight of ashes employed in my experiments, as compared with the weight of the pit-sand, must be regarded as a circumstance highly disadvantageous to a precise appreciation of the worth of the ashes. It is not impossible that, weight for weight, the coal-ashes may support better crops than the pit-sand in question. It is certain only that, while coal-ashes are much better in respect to fertilizing ingredients than the really sterile sands composed wholly of quartz grains, they may be no better than, or even inferior to, some other common sands that farmers have access to. No doubt many a sand could be found of precisely the same fertilizing value as pure coal-ashes. It must be remembered, however, that the coal-ashes actually obtained from house fires are almost always more valuable than those employed in the experiments here described, because of the admixture of wood-ashes to which allusion has already been made. This admixture is so general, and often so large, that it may well be true that coal-ashes of the average quality likely to be applied to the land are really better,

on the whole, than good pit-sand. It is plain, moreover, from the results of the foregoing experiments, that the use of sifted coal-ashes as an absorbent in place of dried earth in Moule's earth-closet, which has been often recommended in this country, is judicious and praiseworthy from the chemical point of view. Ashes which by use in this way have become charged with nitrogenous constituents will undoubtedly be found useful as manure. Sifted ashes may be commended also, instead of loam, as a fit material to mix with concentrated or saline manures, such as ammonium or potassium salts, nitrate of soda, or Peruvian guano, before applying them to the land.

With the exception of the barley and oats in Series A, all the experiments thus far described were made with buckwheat. The results of other trials made with rye and with Indian corn are set forth in the following tables.

Sixteen glass preserve-jars were charged with coal-ashes, such as were used in the experiments of Series D; 525 grammes of the ashes being placed in each jar. Three kernels of rye were planted in each jar on January 16, 1873, and the crops were harvested May 6; that is to say, the rye grew some seven weeks longer than the buckwheat. The jars were exposed to the same conditions and watered with the same chemicals as the buckwheat plants of Series D.

RYE IN COAL-ASHES.

No. of jar.	The ashes were watered with	The crop (harvested May 6, 1873).			
		Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Bore ears.	Remarks.
1	Sulphate of magnesia	1.175	2 plants = 27	2	Only two plants.
2	Sulphate of lime .	0.430	1 " = 6 1 " = 7	0	Only two plants.
3	Chloride of potassium	1.450	1 " = 22 2 " = 33	3	
4	Phosphate of potash	1.185	1 " = 22 1 " = 26	2	Only two plants.
5	Nitrate of potash .	5.090	1 " = 20 1 " = 30	2	Only two plants.
6	Nitrate of lime . .	3.790	1 " = 18 1 " = 22 1 " = 24	2	
7	Nitrate of ammonia	3.195	1 " = 21 1 " = 27	2	Only two plants.
8	Rain-water . . .	1.060	1 " = 23 1 " = 28	2	Only two plants.

RYE IN COAL-ASHES (*continued*).

No. of jar.	The ashes were watered with	The crop (harvested May 6, 1873). Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Bore ears.	Remarks
9	Nitrate of potash and phosphate of potash	4.920	2 plants = 12 to 15	0	Two very bushy plants.
10	Nitrate of lime, phosphate of potash	2.970	1 plant = 12	0	One exceedingly bushy plant.
11	Nitrate of potash and sulphate of magnesia	5.115	1 " = 15 1 " = 31	2	Only two plants.
12	Phosphate of potash and sulphate of lime	0.925	1 " = 15 1 " = 17	1	Only two plants.
13	Phosphate of potash and sulphate of magnesia	0.930	1 " = 21 1 " = 23 1 " = 27	3	
14	Nitrate of lime, phosphate of potash, sulphate of magnesia	4.385	1 " = 29	1	Only one plant.
15	Nitrate of lime, phosphate of potash, and sulphate of lime	- - -	- - - - - - -	- -	Neither of the seeds grew.
16	Nitrate of lime, chloride of potassium, phosphate of potash, sulphate of magnesia	5.170	1 " = 31	3	Only one plant, but that the best of the series.

The comparative yield of dry substance will appear from the following table; the crop obtained by water alone being taken as unity.

No. of the jar.	Chemicals used.	Comparative yield of dry substance; the crop by water alone = 1.
16	Nitrate of lime, chloride of potassium, phosphate of potash, and sulphate of magnesia	4.877
11	Nitrate of potash and sulphate of magnesia . .	4.825
5	Nitrate of potash	4.802
9	Nitrate of potash and phosphate of potash . .	4.642
14	Nitrate of lime, phosphate of potash, and sulphate of magnesia	4.137
6	Nitrate of lime	3.576
7	Nitrate of ammonia	3.014
10	Nitrate of lime and phosphate of potash . . .	2.802
3	Chloride of potassium	1.368
4	Phosphate of potash	1.118
1	Sulphate of magnesia	1.109
8	Rain-water	1.000
13	Phosphate of potash and sulphate of magnesia .	0.877
12	Phosphate of potash and sulphate of lime . .	0.873
2	Sulphate of lime	0.406

For the experiments with corn, sixteen glass preserve-jars were charged with 525 grammes of coal-ashes as before, and two kernels of common yellow corn were planted in each jar January 24, 1873; the jars were placed beside those of Series D, and were watered with the same solutions. The crops were harvested May 2 with the following results: —

MAIZE IN COAL-ASHES.

No. of jar.	The ashes were watered with	The crop (harvested May 2, 1873). Weighed in grammes (dried at 90 to 100 deg's C.).	Grew to height in inches.	Bore ears.	Remarks.
1	Sulphate of magnesia	1.800	1 plant = 8 1 " = 10	0	
2	Sulphate of lime	1.970	2 " = 6	0	
3	Chloride of potassium	4.540	1 " = 10 1 " = 14	0	
4	Phosphate of potash	3.080	1 " = 7 1 " = 9	0	
5	Nitrate of potash	15.740	1 " = 21 1 " = 22	1	
6	Nitrate of lime	7.650	1 " = 10 1 " = 17	1	
7	Nitrate of ammonia	6.720	1 " = 14 1 " = 15	2	
8	Rain-water	0.815	1 " = 4 1 " = 6	0	By an oversight this jar was not planted until Feb. 24.
9	Nitrate of potash and phosphate of potash	17.515	1 " = 20 1 " = 27	3	
10	Nitrate of lime and phosphate of potash	13.295	1 " = 20 1 " = 24	3	
11	Nitrate of potash and sulphate of magnesia	10.750	1 " = 19 1 " = 24	2	
12	Phosphate of potash and sulphate of lime	1.270	1 " = 10	0	Only one plant.
13	Phosphate of potash and sulphate of magnesia	3.950	1 " = 8 1 " = 10	0	
14	Nitrate of lime, phosphate of potash, and sulphate of magnesia	9.700	1 " = 17 1 " = 19	4	
15	Nitrate of lime, phosphate of potash, and sulphate of lime	9.085	1 " = 20 1 " = 22	2	
16	Nitrate of lime, chloride of potassium, phosphate of potash, and sulphate of magnesia	10.840	1 " = 18 1 " = 23	3	

In the following table these results are restated in the order of excellence, i. e. of the amount of dry substance harvested.

No. of the jar.	Chemicals used.	Comparative yield of dry substance.
9	Nitrate of potash and phosphate of potash	17.515
5	Nitrate of potash	15.740
10	Nitrate of lime and phosphate of potash	13.295
16	Nitrate of lime, chloride of potassium, phosphate of potash, and sulphate of magnesia	10.840
11	Nitrate of potash and sulphate of magnesia	10.750
14	Nitrate of lime, phosphate of potash, and sulphate of magnesia	9.700
15	Nitrate of lime, phosphate of potash, and sulphate of lime	9.085
6	Nitrate of lime	7.650
7	Nitrate of ammonia	6.720
3	Chloride of potassium	4.540
13	Phosphate of potash and sulphate of magnesia	3.950
4	Phosphate of potash	3.080
2	Sulphate of lime	1.970
1	Sulphate of magnesia	1.800
12	Phosphate of potash and sulphate of lime	1.270
8	Rain-water	0.815

It will be seen, from the foregoing, that the results obtained by growing rye and Indian corn in coal-ashes confirm those obtained in the experiments made with buckwheat. They indicate that the ashes contain appreciable quantities of potash and phosphoric acid in a condition accessible to plants that are duly supplied with moisture and nitrogenous manure. Like the experiments in Series D, they show, moreover, that the sample of ashes employed for the experiments of 1873 contained or produced a trace of some assimilable nitrogen compound.

Chemical Examination of the Ashes used.

It remained to be seen whether the potash and phosphoric acid in the coal-ashes used were actually less in amount than in the pit-sand, or perhaps more firmly held and better able to resist the solvent forces through whose agency plants obtain their food. To this end the two substances were tested as follows : —

By Analysis it appeared that,

Contained of	Coal-ashes such as were used in Series D.	Pit-sand such as was used in Series D.
	Per cent.	Per cent.
Phosphoric acid	0.050	0.035
Potash	1.470	0.887

It will be remembered that in the experiments where buckwheat was grown in coal-ashes and in pit-sand for comparison the jars contained 525 grammes of the ashes and either 1,000 (Series C) or 1,370 grammes (Series D) of the pit-sand. The object was to fill the jars in each instance, and they were better filled, so far as related to pit-sand, in Series D than in Series C. But from the above analyses it appears that while each jar of the coal-ashes contained 0.26 gramme of phosphoric acid and 7.72 grammes of potash, the jars of pit-sand contained, in Series C, 0.35 gramme of phosphoric acid and 8.87 grammes of potash, and, in Series D, 0.48 gramme of phosphoric acid and 12.15 grammes of potash, so that in both the series the plants growing in the comparatively poor pit-sand were really in presence of a larger amount of the fertilizing substances now in question. The larger mass of the sand more than compensated for the smaller proportion of potash and phosphoric acid contained in it. The question whether these constituents are more firmly held against the action of plants by the pit-sand or by the ashes has therefore not been answered by the foregoing experiments. Perhaps there is no great difference between the two substances in this respect. In some points the experiments of Series C and D would seem to show that the matters in the sand are more readily available for the plant than those in the ashes; but it is hard to judge of this matter from the data in question, since the sand offers a certain mechanical advantage for the growth of plants, as has been said. Contrary to what was supposed at the beginning of the research, it seems, on the whole, not improbable that the mere analysis of the two materials indicates very nearly their comparative power of supplying food to plants placed in favorable conditions. Many other experiments upon these and upon analogous materials must, however, be made before the truth of this supposition can be accepted as proved.

Other experiments upon the chemical composition and behavior of the coal-ashes and pit-sand were made as follows: —

A five-inch glass funnel was filled with the coal-ashes and another with the pit-sand. Distilled water was poured little by little upon the materials until 100 c. c. of liquid had filtered from each of the funnels, after their contents had become saturated with water. The percolates were evaporated to dryness and the residues tested by means of the spectroscope. No reaction but that of sodium was

obtained from the pit-sand residue, while the residue from the coal-ashes gave strong reactions for lithium, sodium, and calcium. Other experiments in which pure saline solutions were used instead of distilled water, were tried in this way upon similar amounts of the ashes and the sand. The results were as follows : —

The residue obtained by using,

A solution containing $3\frac{1}{3}$ per cent of chloride of sodium gave reactions for sodium and calcium in the case of the pit-sand, and for potassium, sodium, calcium, and lithium in the case of the coal-ashes.

A solution containing 5 per cent of nitrate of ammonia gave reactions for sodium and calcium in the case of the sand; and for potassium (strong), calcium, lithium, and sodium in the case of the coal-ashes. Obscure flashes of a broad line in the position of the blue strontium line, or of the lithium line that is visible only at very high temperatures, were noticed several times, but I have not yet found time to determine whether this suggestion of cæsium is really due to the presence of that element in the coal-ashes.

A solution containing 5 per cent of Epsom salt gave very strong reactions for sodium and calcium in the case of the pit-sand.

A solution of chloride of calcium gave reactions for potassium (faint), sodium (obscured), and lithium (strong), in the case of the coal-ashes.

The solution obtained by digesting coal-ashes with pure, strong chlorhydric acid gave reactions for potassium, sodium, calcium, and lithium (strong).

The constant presence of lithium in the coal-ashes led to the following comparative tests, made in the hope of gaining some idea of the relative amount of this element.

Note on the Amount of Lithium in Coal-Ashes.

Every sample of anthracite ashes thus far examined has given a reaction for lithium when tested with the spectroscope. This remark applies not only to the coal-ashes employed in the foregoing experiments, but to several other samples obtained from household fires. The fact that the ashes of many vegetable substances (especially the ash of grains) gave no reaction

for lithium when subjected to precisely similar tests with the spectroscope, goes to show that the amount of this element contained in the coal-ashes is probably relatively large as contrasted with the amounts that have been shown by previous observers to occur in the ashes of the generality of plants. In seeking to elucidate this point the following-named substances were tested with the spectroscope.

A sample of wood-ashes taken from a soap-boiler's stock at Southbridge, in Central Massachusetts, on being percolated with distilled water as above, yielded a residue that gave only the reactions of potassium, sodium, and calcium. In like manner, the solution obtained by digesting a little of these wood-ashes in strong chlorhydric acid gave only the reactions of calcium, potassium, and sodium.

Ashes from the husks of cotton-seed gave no lithium, but a strong reaction for potassium, and a reaction for sodium, both when they were percolated with water and when digested with chlorhydric acid.

The ashes of Manila cheroots, on the contrary, and of ordinary cigars, gave very distinct reactions for lithium, as well as for potassium, sodium, and calcium.

The ashes of eel-grass (*Zostera marina*) from Hingham harbor gave reactions for potassium, sodium, lithium, and calcium, when moistened with strong chlorhydric acid, and so did the ash of black-grass (*Juncus Gerardi*) from a marsh at Hingham. But the ash of the coarser salt-marsh grass (*Spartina stricta*, var. *alterniflora*) from that locality gave only the reactions of potassium, sodium, and calcium.

The ashes of ox-eye daisies (*Leucanthemum vulgare*) grown upon the field from beneath the surface of which the pit-sand of the foregoing experiments was taken, gave very distinct reactions for potassium, sodium, lithium, and calcium, and a suspicion of rubidium also.

The ashes of several ten-gramme samples of maize (grain) from different localities gave only sodium and potassium reactions. But the ash from 6.7 grammes of sweet-corn *cob* from Hingham gave reactions for sodium and potassium (strong) and a rather weak reaction for lithium.

The ash of wheat bran gave only sodium and potassium.

The ashes of common white beans gave a reaction for sodium, and a strong reaction for potassium. Both the pods and stalks grown from such beans upon the Plain-field of the Bussey Institution gave only the reactions of sodium, potassium, and calcium. But the ashes of stalks grown from similar beans planted in the coal-ashes of Series A, and watered with rain-water, gave lithium and potassium.

The ashes of bean-stalks grown in coal-ashes that were watered with nitrate of ammonium gave a strong lithium reaction and a potassium reaction also. When the ashes of these stalks were moistened with strong chlorhy-

dric acid it was noticed that the lithium line persisted long after the potassium line had faded out. Both in this case and in that where the coal-ashes had been watered only with rain-water, the chlorhydric acid solution of the stalk ash gave a faint indication of calcium.

The ashes of bean-stalks grown in coal-ashes that were watered with sulphate of magnesia gave strong reactions for lithium and potassium and a faint reaction for calcium. A similar remark is true of the ash of bean-stalks from coal-ashes watered with phosphate of potash, only that in this last case the lithium reaction, though distinct, was not so brilliant and strong as in the three preceding tests.

0.25 gramme of dry bean-stalks grown in coal-ashes that had been watered with a solution of nitrate of potash, on being reduced to ashes and tested with the spectroscope, gave the reactions of sodium, calcium, potassium, and lithium. But beans, i. e. the seeds obtained from a plant grown in coal-ashes and watered with a potassium salt, gave no lithium, but only potassium and sodium reactions.

The ashes of peat from the Bussey farm gave a very strong reaction for calcium and good reactions for sodium and potassium, besides a faint but distinct lithium reaction.

The ashes of bituminous coal from Sydney, Cape Breton, treated with strong chlorhydric acid, gave reactions for potassium, sodium, lithium, and calcium.

The ashes of English cannel-coal gave strong sodium and calcium reactions, and very faint indications of potassium and lithium.

Fine dust swept from an iron pipe which served as a flue or chimney to the furnace from which the ashes of Series D were obtained, gave reactions for calcium, lithium, potassium, and sodium.

A single attempt was made to determine precisely the amount of lithium in the coal-ashes, by the method recommended by Fresenius in his Quantitative Analysis, New York edition of 1871, p. 161, namely, by precipitation as phosphate, but no satisfactory result was obtained.

1.1147 gramme of the ashes fritted with carbonate of lime and chloride of ammonium, after Lawrence Smith, gave, after the removal of the dissolved lime by means of carbonate of ammonia, 0.0034 gramme of phosphate of lithia, which would be equivalent to 0.00132 gramme of Li_2O, or 0.12 per cent, provided the phosphate had been pure. But on testing the weighed phosphate with the spectroscope, the reactions of calcium, potassium, and sodium were all obtained, beside that of lithium. It seemed probable that the phosphate contained a considerable relative amount of calcium and sodium. In the press of other matters, no attempt has been made as yet to repeat this determination. It would of course be interesting to pursue this inquiry, not only with larger quantities of material, but by means of other analytical processes, until a satisfactory average result should be obtained.

The presence of lithium in such appreciable quantity in the coal-ashes naturally suggests the idea that this substance may have exerted a hurtful influence upon the plants grown in the experiments above recorded. For, as is well known, Nobbe, Schroeder and Erdmann * found that chloride of lithium has a distinctly poisonous action upon buckwheat plants grown by way of water culture, that is to say, not in solid soil, but in water to which minute quantities of the various kinds of plant-food have been added. But the force of the idea is very much lessened, if not wholly destroyed, by a moment's consideration of the results of the experiments in coal-ashes as compared with those made in the sterile sand, since it appears that the plants in the ashes grew as well, when fully fed, as those in the corresponding jars of sand.†

It is not surprising, for that matter, that the poisonous action of lithium should be hindered or annulled when this substance is held combined in an earthy material like ashes, or admixed with the soil. Even such esteemed manures as the ammonium salts are found to act most injuriously upon plants when applied in water culture, unless special precautionary measures be taken.

The water-holding power of the ashes was determined by placing a weighed quantity of the material in a weighed funnel loosely plugged with cotton-wool, and slowly pouring water upon the ashes, a teaspoonful at a time, until a drop appeared in the throat of the funnel. After standing a little to make sure that any excess of water had drained off, the whole was weighed. Under these conditions ashes that had been sifted through a sieve carrying four meshes to the linear inch took up 95.61 per cent of water; while that which had been sifted through a finer sieve carrying twenty-four meshes to the inch took up 110.4 per cent of water.

Before proceeding to determine the power of the coal-ashes to fix and hold potassium, sodium, calcium, magnesium, etc., some preliminary experiments were made to determine the amount of soluble silica, and the amount and character of the matters that can be dis-

* Die landwirthschaftlichen Versuchs-Stationen, 1871, **13**, 327. Compare Birner and Lucanus, Ibid.

† Compare, for example, the results obtained in jars Nos. 14 and 16 of Series D. It is to be remembered, in this connection, that coal-ashes, from their lower specific gravity and lack of porosity and mobility, do not afford so good standing-room for plants as sand. It has been already stated in the text that plants growing in coal-ashes under the conditions of the foregoing experiments are at a certain mechanical disadvantage.

solved out from the ashes by pure water. The results of these experiments are as follows: they were all made upon fine ashes that had been sifted through a sieve which had twenty-four meshes to the linear inch.

To determine the amount of soluble silica, if any, contained in the ashes "in the free state," 50 grammes of the ashes were boiled with a freshly made solution of carbonate of soda, which was subsequently filtered, neutralized with chlorhydric acid, and evaporated to dryness to render the silica insoluble. In one experiment one half of a solution, prepared by dissolving 50 grammes of the crystallized carbonate in 175 c. c. of water, was boiled with the ashes for half an hour, and after the clear liquor had been decanted the other half of the solution was poured upon the ashes and boiled in its turn for a similar length of time; there was obtained 0.0474 per cent of "free soluble silica." In another experiment similar to the foregoing with the exception that the solution of carbonate of soda was half as strong as before, 0.0418 per cent of the free silica was observed. These amounts are, of course, insignificant.

To determine *combined soluble silica* 50 grammes of the ashes were boiled with diluted chlorhydric acid prepared by mixing 50 c. c. of the concentrated acid with 100 c. c. of water. One half of this mixture was boiled upon the ashes for half an hour, the resulting solution was decanted, and the other half of the diluted acid then added and boiled for the same length of time. The washed residue was boiled with a solution of carbonate of soda, as in the trials described in the previous section, and an amount of silica equal to 0.88 per cent of the original ashes was obtained. To this must be added 2.18 per cent of silica, which was dissolved by the chlorhydric acid and recovered therefrom by evaporation in the usual way. Hence the total soluble silica amounted to 3.06 per cent.

In order to determine if the active silicate thus shown to be present in the ashes can combine readily with water, 150 grammes of the ashes were dried at 100° and weighed. 0.10 per cent of hygroscopic water was expelled. The dried ashes were then moistened thoroughly with water and again dried at 100°; a quantity of water amounting to 0.11 per cent of the ashes taken was held in combination. This combined water was not expelled on heating the ashes for some hours at 110°, nor at 150°; but at 200° it was driven off.

In the chlorhydric acid solution of the paragraph next but one preceding, there was found (in terms of per cent of the ashes taken), —

Silica	2.18 (as before)
Alumina, iron, etc.	0.74
Lime	0.76
Magnesia	0.13
Alkalies (in form of chlorides)	0.17

Since a very considerable amount of alkaline chlorides was obtained from the ashes by Lawrence Smith's process, it appears from the foregoing that a good part of the alkaline matters in the ashes must be held with sufficient firmness to resist the action of hot acid of the strength indicated.

To determine the amount of *matter soluble in pure water*, 9250 grammes of the sifted ashes were placed in a clean water-soaked firkin provided with a plug at the bottom and percolated methodically with pure distilled water, free from ammonia. An amount of percolate was collected equal to the volume of water that was required to moisten the ashes to the point that a drop fell from the orifice at the bottom of the firkin. The 10 litres of liquid thus obtained were evaporated to the volume of 4 litres, and definite fractions of the latter were taken for the determinations the results of which are now in question. The total amount of matter dissolved by the water was equal to only 0.114 per cent of the ashes. By analysis it appeared that the water had dissolved from the ashes: —

Silica	0.002%
Alumina, iron, etc.	0.000
Lime	0.036
Magnesia	0.003
Potash	0.00038

besides sulphuric acid in combination with the lime, and as much soda and lithia as were contained in an amount of their mixed chlorides equal to 0.0193 per cent of the ashes taken. During the evaporation of this aqueous solution it was noticed that crystals of gypsum separated freely after a certain degree of concentration had been reached. The residue obtained by evaporating the solution to dryness had a faint but distinct green color. Neither alcohol, ether, nor water had any action upon the coloring matter in the cold, but when

hot either of these liquids discharged the color immediately and completely without forming a colored solution. When a bit of the colored residue was heated upon platinum foil the color became somewhat fainter, apparently by dissemination through the mass of material, rather than from any destruction or alteration. By fusion with nitrate of potash and carbonate of soda upon platinum foil a faint reaction for manganese was obtained. It seemed probable, though not certain, that the green color was due to manganese, —perhaps to the presence of an insoluble manganate. No phosphoric acid could be detected in the concentrated aqueous solution by means of molybdate of ammonia.

It is my intention to have the so-called *absorptive or fixing power* of coal-ashes investigated with care, — i. e. their power to absorb from solutions and to hold potash, ammonia, and similar bases. The few experiments, recorded below, which have already been made in that direction need to be supplemented by others before any very definite conclusions can be drawn from them. The method of experimenting was essentially that described by Peters.* 100 grammes of the sifted ashes were placed in a glass-stoppered bottle with 250 c. c. of the saline solution to be tested. The mixture was shaken at definite times, and, after twenty-four hours had elapsed, a portion of the solution was run through a dry filter that had been previously thoroughly leached, and definite fractions of the filtrate were taken for analysis. The saline matters employed were all prepared from pure chemicals in the first place and recrystallized afterwards.

I. For the *trial with sulphate of potash,* 2.18 grammes of that salt were dissolved in water to the volume of 250 c. c. After twenty-four hours' contact with 100 grammes of ashes, there were found in the solution

0.1090 gramme of lime,
0.7910 " " potash.

No attempt to estimate the amounts of sodium or of lithium was made. There was no magnesia, nor was any matter precipitable by ammonia found in this liquid or in any of those subsequently tested. Since the original solution of sulphate of potash contained 1.1790 grammes of potash, it appears that in this trial 0.3888 gramme of potash was absorbed and fixed by the 100 grammes of ashes.

* Die landwirthschaftlichen Versuchs-Stationen, 2, 29.

II. For the *trial with carbonate of potash*, 1.727 grammes of this salt were dissolved in water to 250 c. c., and there was found in the filtrate, after twenty-four hours' digestion with the ashes, —

0.0090	gramme	of	lime,
0.0058	"	"	magnesia,
1.1195	"	"	potash,

besides an amount of soda and lithia equivalent to 0.0413 gramme of the mixed chlorides of these substances. Since the original solution of carbonate of potash contained 1.1773 grammes of potash, the amount of that substance absorbed by the ashes was 0.0578 gramme.

III. For the *trial with chloride of potassium*, 0.932 gramme of this salt was dissolved in water to 250 c. c. There was found in the filtrate, after twenty-four hours' digestion with the ashes, —

0.0970	gramme	of	lime,
0.0243	"	"	magnesia,
0.5998	"	"	potash,

besides an amount of soda and lithia equivalent to 0.0423 gramme of their mixed chlorides. Since the original solution of chloride of potassium contained only the equivalent of 0.5888 gramme of potash, it would appear that, instead of absorbing any of the potassium of the salt, the coal-ashes gave up 0.011 gramme of it to the solution. Further experiments are needed upon this point.

IV. A partial trial was made with sulphate of ammonia also, 1.4 grammes of the salt being dissolved in water to 250 c. c., and digested with 100 grammes of ashes, as before. There was found in the filtrate

0.1240	gramme	of	lime,
0.1680	"	"	magnesia and alkaline chlorides.

The amount of lime dissolved by the saline solutions from the ashes, as compared with the quantity dissolved by pure water, is decidedly large in every instance, with the exception, naturally, of the solution of carbonate of potash.

No. 5. — *A Record of Trials of various Fertilizers upon the Plain-field of the Bussey Institution.* By F. H. Storer. *First Report.** *Results obtained in* 1871.

The Plain-field of the Bussey Institution is a strip of table-land about seven acres in extent, at the top of a hillock, or ridge, of "drift" or glacial gravel. The ridge rises abruptly from the level of a stream of water called Stony Brook, on the one hand, and from a low, boggy valley on the other. At a height of some ninety or more feet above the bed of the stream the ridge is crowned by a remarkably level plain, of which the "Plain-field," belonging to the University, comprises perhaps one half. A couple of acres of the most level part of the field were selected for the experiments now to be described.

The soil of the Plain-field consists of a thin layer of loam, resting upon a deep bed of coarse, open gravel. No constant supply of water can be obtained by sinking wells in this gravel until a depth of fifty or sixty feet has been reached. Naturally the soil of the field seems to have been remarkably homogeneous throughout, and the portion chosen for the experiments was taken in the belief and upon the assurance that nothing had ever been done to vitiate the original homogeneity; but, as will be seen on inspecting the results recorded below, it turned out that a small patch at one end of the experimental field, comprising Sections A and A A, and touching Section B, as shown in the diagram, was much richer than the rest. With this not very important exception, the field was remarkably well suited for the purpose for which it was taken. It may indeed be regarded as a typical example of the thin, light, "leachy" soils which so frequently overlie the gravelly drift of New England.

In 1870 the field, with the exception of Sections A and A A, had carried a crop of winter rye (unmanured), which was wellnigh destroyed by a hail-storm in the spring of that year. Previous to the time when the rye was planted, the field had been down to grass some six or eight years, without manure. Before the grass a small crop of Indian corn had been taken from the land.

* Presented to a Committee of the Trustees of the Massachusetts Society for Promoting Agriculture, December 3, 1871.

Purpose of the Experiments. — It was determined to test upon the soil of this typical field the action of various fertilizers easily procurable in Boston. In order to allow for the varying influence of the seasons in different years, and for the sake of determining what would be the result of incessantly cropping such poor land, it was decided to continue the same set of experiments, without changing the kinds of crops or of manures, for as many successive years as experience might suggest.

Arrangement of the Plots.—A portion of the field was divided into sections and plots, as will appear from the diagram on the next page.

There were four distinct divisions of the experimental field, stretching across it, as will be seen upon the diagram, looking from right to left. Each of these divisions was separated into two sections, marked A and AA, B and BB, etc. Each section was subdivided into three sets of plots, and each set of plots was, in its turn, divided into nine small squares. To each division some one general class of manures was applied, but in somewhat different ways to the sections or halves of divisions. Each of the three sets of plots in every section carried a special kind of crop, and each of the final squares received either a particular variety of manure or a special quantity of manure, excepting always the middle square (No. 5) in each set of plots, which got no manure whatever. The manner in which the sets of plots and the final squares or units were arranged, marked, and numbered will appear from the diagram. Each of the final squares or units was 5×5 metres (1 rod $=$ 5.0291 metres), i. e. very nearly $\frac{1}{162}$ of an English acre. The walks between the squares and plots were one third of a metre wide, that is to say, about one foot wide. Between the main divisions there were walks one metre wide.*

* It may here be said that three years' experience has fully justified the fitness of this arrangement for the field in question, both as regards the size of the squares and the width of the walks. Where a considerable number of manures are to be tested simultaneously, small plots are essential in order that the labor may all be performed by one or two trusty men; that the processes of planting, cultivating, and harvesting may be made, in some sense, simultaneous, and consequently under equal or nearly equal conditions; and finally, in order that proper storage-room may be found for the crops produced, where they may be brought to some one uniform condition of dryness before weighing, and may be weighed at one and the same time.

Narrow walks between the plots and squares are desirable in order that no land shall be wasted, and that some approach to uniformity of soil among the different

plots may be secured by confining the experiments as closely as possible to one and the same part of the field. Up to the present time, December, 1873, nothing has occurred in any of my experiments to indicate either that the manures applied to one square have ever soaked into the soil of adjacent squares, or that the roots of any of the crops have made use of fertilizers that were not applied for their especial benefit.

Kinds of Crops. — Each of the manures was tested with three kinds of crops; namely, barley, beans, and ruta-bagas, as will appear below. Three kinds of crops were chosen, not only for the sake of testing the manures with different plants, but in order that some one crop might succeed each year, no matter whether the season should be dry or wet.

Manures. — Upon one division of the experimental field the various kinds of lime procurable in Boston were tested, together with gypsum, ground oyster-shells (as fine as wheat-flour), spent-lime from gas-works and from a soap-boiler, and a mixture of lime and salt. The lime from the gas-works was originally oyster-shell lime, but that from the soap-boiler, which had served to remove carbonic acid from soda-ash, was probably made from the limestone of Rockland, in Maine. A comparatively large quantity of the soap-boiler's waste was used because of the wet and sticky condition in which that material came to hand. To one half the division (Section A) the lime or lime-compound was applied by itself, while upon the other half (Section AA) the lime was admixed with peat. The original purpose of these trials was to determine what effect would be produced upon a poor drift soil by liming it heavily and repeatedly during a term of years.

On the next division of the field several potash-compounds, besides fish-scrap, Peruvian guano, and sulphate of ammonia, were contrasted with farm-yard manure and Boston stable-manure. Upon one section (marked B) of this division the several fertilizers were applied in the proportions ordinarily used by farmers, while upon the other section (BB) the same kinds of materials were applied in considerably larger quantities, with the intention that each square should receive an amount of fertilizing material equal in money-cost, as nearly as might be, to that put upon each of the other squares. For these comparisons, — which, as regards the cost and the amount of the fertilizers to be taken, are of course no more than rough approximations to the truth, — farm or stable manure was taken as the standard, and $ 12 per cord was allowed as the total cost of producing, transporting, and applying it. It was applied at the rate of ten cords to the acre. It would have been possible, no doubt, to have obtained several of the fertilizers at prices low enough to have permitted their application in decidedly larger quantities than were really used. Very much less than an equal money-value of fish-scrap was applied to the square numbered 3, through fear of hurting the crops.

The third division of the field was devoted to phosphates of lime applied in the ordinary proportions to the plots in Section C, and by equal money-values to the plots of Section CC. The standard of comparison in this case was the highest priced superphosphate. Upon Section D several nitrogenous manures were applied in chemically equivalent quantities, and Section DD was devoted to various salts and fertilizers not otherwise provided for; they were applied, as nearly as might be, at the rates ordinarily used by farmers.

It was no part of my plan to apply at this stage of the research any mixtures of fertilizers which could be regarded as complete manures, or could pretend to compete with the dung of animals. It was thought that such mixtures, proper for the soil of the experimental field, could probably be best prepared in the light of the results of one or two years' experience with single fertilizers. With the view, however, of using mixtures in future years, a considerable part of the experimental field, upon three sides of the portion occupied by the plots represented in the foregoing diagram, was left fallow for the present.

Preparation of the Field, and Methods of Manuring and Planting it. — The entire field was ploughed four inches deep, April 5 – 7; it was then harrowed parallel with the furrows, and finally cross-harrowed, before the plots were staked out. With the exception of the dungs and peat and one heavy dressing of wood-ashes, which were measured, each of the fertilizers was carefully weighed and spread evenly upon the surface of the plots. The heavy manures, such as stable-manure, peat, lime, ashes, and leather-scraps, were spaded under; bone-meal, fish-scrap, guano, flocks, oil-cake, and pearlash were raked in, while the superphosphates and various salts and chemicals were simply mixed with a portion of the earth of their respective squares, and then spread upon the surface of the ground, without spading or raking.

The *barley* (ordinary two-rowed seed-barley, from Messrs. J. Breck & Son, of Boston) was sown towards the close of April at the rate of two bushels per acre, or 0.4 quart (= 292 grammes) to each of the 5 × 5 metre squares. It was spread evenly upon the surface of the ground, raked in as thoroughly as possible, and the soil smoothed down upon it with the flat of a spade. The ripe plants were finally pulled up by hand in order that they might be harvested free from weeds, and that each crop should be collected precisely in the same way and as completely as the others. The soil that adhered to the

roots was readily removed after it had become dry, so that the amount of it weighed with the "total crop" was insignificant.

The *beans* ("medium" white bush-beans, from the seed-store of J. Breck & Son) were sown early in May, in little drills or furrows one half-metre apart. Each bean was dropped eight centimetres from its neighbors, and covered with an inch of earth. The total weight of beans planted on each square was about 375 grammes. The beans were hoed frequently during the summer. The plants were finally pulled up by the roots after the beans had been picked.

The *ruta-bagas* were sown late in May, at a time of severe drought which lasted through several subsequent weeks. It was consequently a long time before the young plants appeared above the surface of the ground, and few of them ever overcame the hardships encountered in their youth. Doubtless some of the fertilizers employed did more harm than good under the circumstances.

Character of the Season. — A cold rain-storm of several days' duration, at the end of April, checked the growth of much of the barley. A severe drought in May and June ruined the ruta-bagas and hurt the barley somewhat ; the beans, however, did well.

The stone building of the Bussey Institution not being completed in season to receive the barley, that crop had to be stored in a barn-cellar, where it suffered somewhat from the depredations of rats during the interval between harvesting and weighing. Since it was impossible to tell how much the several sheaves had suffered in this way, suspicion is necessarily cast upon the entire barley-crop of 1871. It is to be observed, therefore, that none of the figures under the headings "grain" and "total product" in the table for barley can be regarded as strictly accurate, though, doubtless, many of them are so. Only the column which gives the yield of "straw and chaff" is correct, or very nearly correct in each particular. With this exception, the precise weight of each of the crops obtained from the several fertilizers will appear from the following tables. The weights of fertilizers used and of crops obtained are stated either in terms of kilogrammes or grammes.*

* One gramme equals 15.4346 grains English. 1000 grammes equal 1 kilogramme or 2.2 lbs. avoirdupois, very nearly.

Section A. — Kinds and Weights of Crops, in Kilogrammes. 1871.

Weights of fertilizers, in kilogrammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
13.65 kilogrammes spent-lime from Boston gas-works	1	5.202	22.298	27.500	10.425	9.425	19.850	54.25	28.00	82.25
13.65 kilogrammes oyster-shell flour .	2	7.525	24.575	32.100	11.300	10.950	22.250	54.75	31.75	86.50
13.65 kilogrammes of lime from oyster-shells	3	8.055	23.695	31.750	10.150	10.850	21.000	60.60	33.25	93.85
15 kilogrammes spent-lime from soap-boilers	4	7.020	20.850	27.870	8.960	8.290	17.250	37.25	25.00	62.25
No manure	5	7.090	21.780	28.870	7.300	8.150	15.450	52.25	29.75	82.00
13.65 kilogrammes of Rockland lime .	6	7.975	22.525	30.500	4.110	8.140	12.250	44.75	23.75	68.50
0.307 kilogrammes of common salt and 13.65 kilogrammes of lime from oyster-shells	7	6.807	18.063	24.870	7.210	8.040	15.250	41.75	40.00	81.75
13.65 kilogrammes of powdered gypsum	8	8.000	21.750	29.750	3.455	6.145	9.600	43.25	38.10	81.35
13.65 kilogrammes of Brandon lime .	9	8.540	21.460	30.000	2.900	7.400	10.300	38.50	37.75	76.25

Note. — It will be noticed that of the fertilizers applied to Section A, the oyster-shell flour and the oyster-shell lime seem to have produced a distinctly good effect, while the soap-boiler's waste and the gypsum did, on the whole, harm rather than good.

As has been already stated on page 80, the soil of the entire division devoted to trials of limes differed very decidedly from that of the other three divisions of the experimental field, — a fact to which the crops obtained from it bear witness. On inquiry, it appeared that the land of this division had not formed a part of the old rye-field of 1870 (see p. 80). On the contrary, the strip in question had been well manured in that year, and had been planted with ruta-bagas. But the summer had been very dry, the ruta-bagas had failed almost completely, and the manure which they should properly have consumed had been left in the land to interfere with the experiments here recorded. The mechanical condition, moreover, of the soil in Sections A and AA, was very different from that of the remainder of the experimental field; it had the appearance of having been cultivated for many years. For further remarks on the soil of this section, see the note under the next table.

Section AA. — Kinds and Weights of Crops, in Kilogrammes. 1871.

Weights of fertilizers, in kilogrammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
All the squares were manured in precisely the same way as those of Section A, with the addition of eight cubic feet of peat to each and every square.	1	7.435	15.565	23.000	7.530	8.970	16.500	53.75	33.50	87.25
	2	5 300	21.200	26.500	9.655	9.095	18.750	59.75	34.75	94.50
	3	6.700	22.900	29.600	9.010	9.940	18.950	66.75	46 85	113.60
	4	4.912	18.088	23.000	8.075	9.475	17.550	39.00	25.10	64.10
	5	4.812	19.938	24.750	7.715	8.585	16.300	39.40	26.65	66.05
	6	5.820	22.430	28.250	3.980	9.420	13.400	39.75	31.85	71.60
	7	5.190	16.060	21.250	8.110	8.240	16.350	36.00	35.55	71.55
	8	6.350	19.150	25.500	5.670	9.130	14.800	34.75	31.90	66.65
	9	7.570	22.030	29.600	4.155	8.845	13.000	43.00	44.25	87.25

Note. — What has been said in the note to Table A applies almost equally well to the results obtained on Section AA. The oyster-shell products did good, but the peat seems to have had little or no beneficial action. The peat employed came from the Bussey Farm, and had lain over winter in heaps at one end of the Plain-field. Although the soil of this section was not so good as that of A, it was nevertheless better than that of the rest of the experimental field. It must be carefully borne in mind that the results obtained by using lime upon the comparatively rich soil of Sections A and AA cannot be compared with those obtained upon the other sections of the field by the use of the various fertilizers. The lime results have little or no interest, excepting in so far as they may be compared one with another. They have no bearing upon the general question, What sort of manure should be applied to a thin, poor soil overlying the New England "drift"? *

* The experience of subsequent years (1872 and 1873) has only made this conclusion more precise and emphatic. It would, on some accounts, have been better not to have reported the results with lime at the same time with the others, since they have scarcely any thing in common with the rest.

Section B. — Kinds and Weights of Crops, in Kilogrammes. 1871.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
8 cubic feet of farm-manure from Mr. Motley's barn-cellar	1	2.570	18.530	21.100	7.380	8.620	16.000	67.50	39.50	107.00
8 cubic feet of "long" horse-manure from a city livery-stable	2	2.590	16.160	18.750	9.090	9.060	18.150	50.25	41 50	91.75
972 grammes of fish-scrap	3	0.970	4.130	5.100	0.935	3.065	4.000	7.00	13.50	20.50
4095 grammes of wood-ashes	4	1.570	7.180	8.750	4.740	5.810	10.550	19.25	19.25	38.50
No manure	5	1.120	3.880	5.000	0.565	3.185	3.750	2.75	8.25	11.00
307 grammes of pearl-ash	6	2.080	7.670	9.750	4.550	4.850	9.400	21.75	14.75	36.50
307 grammes of sulphate of potash .	7	1.035	4.365	5.400	3.675	5.575	9.250	21.25	22.00	43.25
307 grammes of sulphate of ammonia .	8	2.480	8.770	11.250	6.255	6.445	12.700	32.25	20.25	52.50
No manure (in default of leached ashes)	9	2.590	7.410	10.000	4.460	6.790	11.250	23.75	17.75	41.50

Note. — It was observed at the time of planting, i. e. after the squares had all been staked out, that there was an old strip of wood-ashes in the walk between the sections A and B. It appeared that these ashes had been applied the previous year to a part of a ruta-baga field that had comprised the whole of Sections A and AA, and an extremely narrow slice at one corner of Section B. Happily most of the ash-strip fell within the limits of the walk between A and B; but it could be seen both before the planting and during the growth of the crops, that the ashes lapped over the edge of the walk into parts of the squares A, 1, 2, and 3, devoted to barley, and A, 1, 2, and 3, devoted to beans, and less decidedly into squares B, 7, 8, 9 (barley), and B, 7, 8, and 9 (beans), where they faded out. The effect of these contaminating ashes may be clearly seen upon the table of results, particularly in the case of the crops obtained from the squares numbered 9, to which, as it happened, no fertilizers were applied.

Section BB. — Kinds and Weights of Crops, in Kilogrammes. 1871.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
8 cubic feet of farm-manure from Mr. Motley's barn-cellar	1	5.145	18.255	23.400	5.065	10.035	15.100	81.00	47.25	128.25
8 cubic feet of long horse-manure from a city stable	2	4.000	15.850	19.850	7.550	9.300	16.850	68.25	45.50	113.75
2916 grammes of fish-scrap	3	2.680	11.070	13.750	6.200	9.050	15 250	13.25	29.50	42.75
3 bushels of wood-ashes	4	4.725	15.375	20.100	8.230	7.270	15.500	63.75	37.50	101.25
No manure	5	1.550	4.950	6 500	2.450	4.350	6.800	6.00	17.75	23.75
1336 grammes of pearlash	6	2.095	6.905	9.000	6.605	7.095	13.700	34.50	30.50	65.00
2267 grammes of sulphate of potash .	7	4.630	13.870	18.500	7.230	7.270	14.500	41.00	32.00	73.00
4987 grammes of sulphate of ammonia	8	2.990	9.610	12.600	4.020	4.580	8.600	16.50	29.25	45.75
No manure	9	2.850	7.250	10.100	3.450	5.100	8.550	18.00	26.00	44.00

Note. — Most of the fertilizers applied to Sections B and BB, that is to say, the potassic manures and dungs, produced distinctly good effects. The results obtained by the use of the "long" strawy horse-manure are noteworthy, since they compare very well with those given by the excellent farm-manure obtained from Mr. Motley. The heavy dressing of wood-ashes gave excellent results, and so did several of the other heavy dressings. The light dressing of fish-scrap did little or no good.

Section C. — Kinds and Weights of Crops, in Kilogrammes. 1871.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
1365 grammes of bone-meal from W. L. Bradley	1	0.200	7.200	7.400	2.185	3.915	6.100	12.25	10.75	23.00
972 grammes of Peruvian guano	2	0.465	9.935	10.400	1.545	4.105	5.650	25.75	14.00	39.75
1365 grammes of Wilson's superphosphate	3	0.617	9.633	10.250	1.075	4 375	5.450	35.25	20.25	55.50
1638 grammes of crushed bone from J. Breck and Son	4	0.593	8.407	9.000	3.575	5.675	9.250	12.75	19.00	31.75
No manure	5	0.747	6.653	7.400	1.575	4.375	5.950	9.25	13.00	22.25
819 grammes of floated bone from Boston Milling and Manfacturing Company	6	0.955	9.145	10.100	0.840	3.560	4.400	10.50	14.00	24.50
1365 grammes of Bay State superphosphate	7	0.852	6.648	7.500	3.000	5.250	8.250	19.75	20.00	39.75
1365 grammes of Coe's superphosphate	8	0.762	6.638	7.400	2.020	3.930	5.950	12.75	21.00	33.75
1365 grammes of Bradley's "X. L." superphosphate	9	1.692	8.708	10.400	1.225	3.875	5.100	13.25	18.25	31.50

Note. — The effects produced by the phosphatic fertilizers in Sections C and CC are decidedly inferior to those obtained from the potash compounds of the preceding sections. A few of the "superphosphates" made themselves felt to a certain extent, and so did the Peruvian guano in the case of the grain crop, but none of the results are encouraging. Several of the crops obtained by the use of bone-meals were worse than where nothing was applied to the land. The extremely fine "floated" bone-dust produced little or no good effect, excepting in a single instance. On the whole it did more harm than good. See further, as regards this matter, the remarks on page 94.

Section CC. — KINDS AND WEIGHTS OF CROPS, IN KILOGRAMMES. 1871.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
1869 grammes of Bradley's bone-meal	1	1.472	8.628	10.100	0.755	4.045	4.800	23.75	21.25	45.00
1068 grammes of Peruvian guano . .	2	1.968	12.432	14.400	2.265	4.785	7.050	22.50	22.00	44.50
1485 grammes of Wilson's superphosphate	3	1.581	8.919	10.500	1.290	3.860	5.150	8.25	18.00	26.25
1365 grammes of Breck's flour of bone	4	1.475	11.525	13.000	0.985	4.115	5.100	21.00	17.25	38.25
No manure	5	2.942	10.058	13.000	0.730	3.970	4.700	24.75	16 25	41 00
1000 grammes of floated bone . . .	6	2.740	7.860	10.600	0.715	3.585	4.300	10.75	14.00	24.75
1365 grammes of Bay State superphosphate	7	1.490	10.610	12.100	3.860	6.790	10.650	17.50	17.00	34.50
1450 grammes of Coe's superphosphate	8	2.747	11.653	14.400	3.240	6.860	10.100	13.00	20.50	33 50
1365 grammes of Bradley's "X. L." superphosphate	9	2.482	12.768	15.250	1.835	5.115	6.950	9.75	23.00	32.75

NOTE. — No real superphosphate, free from admixture with fish-scrap or some such nitrogenized compound, could be procured in the Boston market in 1871. In view of the fact that all the so-called superphosphates employed in these experiments were highly nitrogenized as well as phosphatic, the little effect produced by them is remarkable. Analyses of these products have been given on page 8 *et seq.* On comparing the weights of the crops harvested from the two sections, it will be seen that the soil of C is somewhat inferior to that of CC.

Section D. — Kinds and Weights of Crops, in Kilogrammes. 1871.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
144.5 grammes of nitrate of ammonia	1	1.205	4.795	6.000	0.575	3.825	4.400	11.25	20.50	31.75
307 grammes of nitrate of soda . . .	2	2.190	8.310	10.500	0.415	3.185	3.600	24.00	19.25	43.25
238.33 grammes of sulphate of ammonia	3	1.512	9.588	11.100	0.335	3.515	3.850	14.50	21.25	35.75
238.33 grammes of sulphate of ammonia plus 314.5 grammes of sulphate of potash	4	2.885	9.515	12.400	3.785	4.465	8.250	23.25	10.00	33.25
No manure	5	1.780	6.220	8.000	0.455	2.645	3.100	34.50	9.25	43.75
193 grammes of chloride of ammonium	6	1.430	6.820	8.250	1.415	3.685	5.100	28.25	18.25	46.50
365 grammes of nitrate of potash . .	7	3.305	8.795	12.100	3.290	4.360	7.650	25.25	14.50	39.75
238.33 grammes of sulphate of ammonia, plus 581.5 grammes of sulphate of soda	8	3.077	9.523	12.600	0.470	3.130	3.600	17.75	6.50	24.25
213 grammes of carbonate of ammonia	9	2.357	7.643	10.000	0.720	2.630	3.350	23.25	11.00	34.25

Note. — The nitrogenous fertilizers of Section D produced but little effect. Nitrate of potash, and the mixture of the sulphate of potash and sulphate of ammonia, did best. Some of the ammonium salts helped the grain a little, but, with a single exception, they did the beans (seeds) no real good. It was to be expected, of course, that the nitrogenous fertilizers should increase the yield of leaves.

Section DD. — KINDS AND WEIGHTS OF CROPS, IN KILOGRAMMES. 1871.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
307 grammes of nitrate of soda . . .	1	2.315	8.185	10.500	0.375	3.875	4.250	23.00	35.75	58.75
307 grammes of roasted salt-cake (sulphate of soda)	2	3.450	9.650	13.100	1.050	4.350	5.400	25.25	33.00	58.25
307 grammes of silicate of soda . . .	3	2.830	9.170	12.000	0.440	4.010	4.450	20.00	31.25	51.25
307 grammes of nitrate of potash . .	4	4.180	13.570	17.750	4.530	5.020	9.550	35.75	30.35	66.10
No manure	5	2.762	8.488	11.250	2.030	4.220	6.250	24.00	23.50	47.50
154 grammes of common salt . . .	6	3.790	10.310	14 100	0.950	3.400	4.350	18.75	21.50	40.20
307 grammes of cotton-seed meal . .	7	2.307	7.943	10.250	0.245	2.355	2.600	26.75	21.90	48.65
2730 grammes of flocks (finely powdered woollen rags)	8	2.922	8.678	11.600	1.015	2.835	3.850	25.50	22.65	48.15
2730 grammes of leather-parings . .	9	3.090	7.660	10.750	0.910	2.790	3.700	14.00	19.35	33.35

NOTE. — In Section DD, nitrate of potash alone was really useful. It is noteworthy that the barley crop was increased somewhat by the application of common salt and sulphate of soda (roasted salt-cake); the effect of both these substances upon the yield of leaves is remarkable. The soil of Section DD was naturally rather better than that of D. The last-named section was, moreover, somewhat shaded by elm-trees, and had been sapped of nourishment, no doubt, by their roots, to a certain extent.

Next to the good effects produced by the potassic manures, the bad results obtained by the use of bone-dust, in Sections C and CC, are specially noteworthy. I had been so often assured by experienced persons, before these experiments were begun, that bone-dust, particularly in dry seasons, often produces very little useful effect upon our drift soils, that it was no matter for surprise to see the phosphatic manures fail in most instances. But I was not prepared for the actual harm that seems to have been done by these manures in several cases.

Since this report was written, I have noticed* that Professor May of the agricultural school at Bayreuth has likewise observed that some of the phosphatic manures employed by him in a set of field experiments were not only useless, but distinctly prejudicial to the growth of wheat and barley.

So few methodical field experiments have been made hitherto upon very poor soils that it is no great wonder that the tendency of the phosphates to hurt a struggling crop should have been overlooked. I have tried a number of experiments in pots, with the view of determining how large an amount of phosphatic manure may be safely applied to sterile land, and from the results already obtained it would seem that bone-dust and other phosphates, when present in too large quantity, may exert an exceedingly hurtful influence upon the development of the plumule or first sprout that springs from the seed, especially at the time when the young shoot is ceasing to draw nourishment from the seed, and is beginning to live upon matters derived from the soil and from the air. It would seem that the seedling cannot endure the presence of a certain excess of phosphate of lime, — at least when the soil in which it stands is too poor to supply at once all the food that the plant may need. If too much of the phosphate should happen to come in contact with a seed, the young plant that springs therefrom is liable to perish almost at its birth, or to suffer so severely in the struggle to gain an independent foothold on the soil that it remains weak and stunted for a long time. It may yet be found that one advantage in using superphosphate of lime as a fertilizer consists in the ability of the soluble phosphoric acid that is contained in that substance to get out of the way of the young plants; that is to say, to diffuse itself so thoroughly in the soil that no hurtful excess of an active phosphate can be anywhere encountered by their roots.

* In Biedermann's Central-Blatt für Agrikulturchemie, October, 1872, 2. 204.

In order that the merit of the several fertilizers used upon any given section may be readily compared, the results laid down in the preceding tables have been rearranged in the tables below in the order of excellence. The best result obtained with each kind of crop is given at the top of the column, and the worst result at the bottom. Between these extremes each particular crop, and the weight of it harvested, will be found in its appropriate place. As before, the weights are in terms of kilogrammes and decimal fractions of kilogrammes.

Tables showing the Best and the Worst Crops obtained from each Section *of the Field.*

Section **A.—Barley.**—1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
9	8.540	2	24.575	2	32.100
3	8.055	3	23.695	3	31.750
8	8.000	6	22.525	6	30.500
6	7.975	1	22.298	9	30.000
2	7.525	5	21.780	8	29.750
5	7.090	8	21.750	5	28.870
4	7.020	9	21.460	4	27.870
7	6.807	4	20 850	1	27.500
1	5.202	7	18.063	7	24.870

Section **A.—Beans.**—1871.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	11.300	2	10.950	2	22.250
1	10.425	3	10.850	3	21.000
3	10.150	1	9.425	1	19.850
4	8.960	4	8.290	4	17.250
5	7.300	5	8.150	5	15.450
7	7.210	6	8.140	7	15.250
6	4.110	7	8.040	6	12.250
8	3.455	9	7.400	9	10.300
9	2.900	8	6.145	8	9.600

Section **A.—Ruta-Bagas.**—1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
3	60.50	7	40.00	3	93.85
2	54.75	8	38.10	2	86.50
1	54.25	9	37.75	1	82.25
5	52.25	3	33.25	5	82.00
6	44.75	2	31.75	7	81.75
8	43.25	5	29.75	8	81.35
7	41.75	1	28.00	9	76.25
9	38.50	4	25.00	6	68 50
4	37.25	6	23.75	4	62.25

Section **AA.—Ruta-Bagas.**—1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
3	66.75	3	46.85	3	113.60
2	59.75	9	44.25	2	94.50
1	53.75	7	35.55	1 }	87.25
9	43.00	2	34.75	9 }	
6	39.75	1	33.50	6	71.60
5	39.40	8	31.90	7	71.55
4	39.00	6	31.85	8	66.65
7	36.00	5	26.65	5	66.05
8	34.75	4	25.10	4	64.10

SECTION **AA. — Barley.** — 1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
9	7.570	3	22.900	3	29.60
1	7.435	6	22.430	9	
3	6.700	9	22.300	6	28.25
8	6.350	2	21.200	2	26.50
6	5.820	5	19.938	8	25.50
2	5.300	8	19.150	5	24.75
7	5.190	4	18.088	1	23.00
4	4.912	7	16.060	4	
5	4.812	1	15.565	7	21.25

SECTION **AA. — Beans.** — 1871.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	9.655	3	9.940	3	18.950
3	9.010	4	9.475	2	18.750
7	8.110	6	9.420	4	17.550
4	8.075	8	9.130	1	16.500
5	7.715	2	9.095	7	16.350
1	7.530	1	8.970	5	16.300
8	5.670	9	8.845	8	14.800
9	4.155	5	8.585	6	13.400
6	3.980	7	8.240	9	13.000

SECTION **B. — Barley.** — 1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
2	2.590	1	18.530	1	21.10
1	2.570	2	16.160	2	18.75
8	2.480	8	8.770	8	11.25
6	2.080	6	7.670	6	9.75
4	1.570	9	7.410	4	8.75
5	1.120	4	7.180	7	5.40
7	1.035	7	4.365	3	5.10
3	0.970	3	4.130	5	5.00
		5	3.880		

SECTION **B. — Beans.** — 1871.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	9.090	2	9.060	2	18.150
1	7.380	1	8.620	1	16.000
8	6.255	9	6.790	8	12.700
4	4.740	8	6.445	9	11.250
6	4.550	4	5.810	4	10.550
9	4.460	7	5.575	6	9.400
7	3.675	6	4.850	7	9.250
3	0.935	5	3.185	3	4.000
5	0.565	3	3.065	5	3.750

SECTION **B. — Ruta-Bagas.** — 1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
1	67.50	2	41.50	1	107.00
2	50.25	1	39.50	2	91.75
8	32.25	7	22.00	8	52.50
9	23.75	8	20.25	7	43.25
6	21.75	4	19.25	9	41.50
7	21.25	9	17.75	4	38.50
4	19.25	6	14.75	6	36.50
3	7.00	3	13.50	3	20.50
5	2.75	5	8.25	5	11.00

SECTION **BB. — Ruta-Bagas.** — 1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
1	81.00	1	47.25	1	128.25
2	68.25	2	45.50	2	113.75
4	63.75	4	37.50	4	101.25
7	41.00	7	32.00	7	73.00
6	34.50	6	30.50	6	65.00
9	18.00	3	29.50	8	45.75
8	16.50	8	29.25	9	44.00
3	13.25	9	26.00	3	42.75
5	6.00	5	17.75	5	23.75

SECTION **BB.—Barley.**—1871. SECTION **BB.—Beans.**—1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.	Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
1	5.145	1	18.255	1	23.40	4	8.230	1	10.035	2	16.850
4	4.725	2	15 850	4	20.10	2	7.550	2	9.300	4	15.500
7	4.630	4	15.375	2	19.85	7	7.230	3	9.050	3	15.250
2	4.000	7	13.870	7	18.50	6	6.605	4 }	7.270	1	15.100
8	2.990	3	11.070	3	13.75	3	6.200	7 }		7	14.500
9	2.850	8	9.610	8	12.60	1	5.065	6	7.095	6	13.700
3	2.680	9	7.250	9	10.10	8	4.020	9	5.100	8	8.600
6	2.095	6	6.905	6	9.00	9	3.450	8	4.580	9	8 550
5	1.550	5	4.950	5	6.50	5	2.450	5	4.350	5	6.800

SECTION **C.—Barley.**—1871. SECTION **C.—Beans.**—1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.	Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
9	1.692	2	9.935	2 }	10.400	4	3.575	4	5.675	4	9.250
6	0.955	3	9.633	9 }		7	3.000	7	5.250	7	8.250
7	0.852	6	9.145	3	10.250	1	2.185	3 }	4.375	1	6.100
8	0.762	9	8.708	6	10.100	8	2.020	5 }		5 }	5.950
5	0.747	4	8.407	4	9.000	5	1.575	2	4.105	8 }	
3	0.617	1	7.200	7	7.500	2	1.545	8	3.930	2	5.650
4	0.593	5	6.653	1 }		9	1.225	1	3.915	3	5.450
2	0.465	7	6.648	5 }	7.400	3	1.075	9	3.875	9	5.100
1	0.200	8	6.638	8 }		6	0.840	6	3.560	6	4.400

SECTION **C.—Ruta-Bagas.**—1871. SECTION **CC.—Ruta-Bagas.**—1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.	Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
3	35.25	8	21.00	3	55.50	5	24.75	9	23 00	1	45.00
2	25.75	3	20.25	2 }	39.75	1	23.75	2	22.00	2	44.50
7	19.75	7	20.00	7 }		2	22.50	1	21.25	5	41.00
9	13.25	4	19.00	8	33.75	4	21.00	8	20.50	4	38.25
4 }	12.75	9	18.25	4	31.75	7	17.50	3	18.00	7	34 50
8 }		2 }	14.00	9	31.50	8	13.00	4	17.25	8	33.50
1	12 25	6 }		6	24.50	6	10.75	7	17.00	9	32.75
6	10.50	5	13.00	1	23.00	9	9.75	5	16.25	3	26.25
5	9.25	1	10.75	5	22.25	3	8.25	6	14.00	6	24 75

SECTION **CC.** — **Barley.** — 1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
5	2.942	9	12.768	9	15.250
8	2.747	2	12.432	2	14.400
6	2.740	8	11.653	8	
9	2.482	4	11.525	4	13.000
2	1.968	7	10.610	5	
3	1.581	5	10.058	7	12.100
7	1.490	3	8.919	6	10.600
4	1.475	1	8.628	3	10.500
1	1.472	6	7.860	1	10.100

SECTION **CC.** — **Beans.** — 1871.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
7	3.860	8	6.860	7	10.650
8	3.240	7	6.790	8	10.100
2	2.265	9	5.115	2	7.050
9	1.835	2	4.785	9	6.950
3	1.290	4	4 115	3	5.150
4	0.985	1	4.045	4	5.100
1	0.755	5	3.970	1	4.800
5	0.730	3	3.860	5	4.700
6	0.715	6	3.585	6	4.300

SECTION **D.** — **Barley.** — 1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
7	3.305	3	9.588	8	12.60
8	3.077	8	9.523	4	12.40
4	2.885	4	9.515	7	12.10
9	2.357	7	8.795	3	11.10
2	2.190	2	8.310	2	10.50
5	1.780	9	7.643	9	10.00
3	1.512	6	6.820	6	8.25
6	1.430	5	6.220	5	8.00
1	1.205	1	4.795	1	6.00

SECTION **D.** — **Beans.** — 1871.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	3.785	4	4.465	4	8.250
7	3.290	7	4.360	7	7.650
6	1.415	1	3.825	6	5.100
9	0.720	6	3.685	1	4.400
1	0.575	3	3.515	3	3.850
8	0.470	2	3.185	2	3.600
5	0.455	8	3.130	8	
2	0.415	5	2.645	9	3.350
3	0.335	9	2.630	5	3.100

SECTION **D.** — **Ruta-Bagas.** — 1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
5	34.50	3	21.25	6	46.50
6	28.25	1	20.50	5	43.75
7	25.25	2	19.25	2	43.25
2	24.00	6	18.25	7	39.75
4	23.25	7	14.50	3	35.75
9		9	11.00	9	34.25
8	17.75	4	10.00	4	33.25
3	14.50	5	9.25	1	31.75
1	11.25	8	6.50	8	24.25

SECTION **DD.** — **Ruta-Bagas.** — 1871.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
4	35.75	1	35.75	4	66.10
7	26.75	2	33.00	1	58.75
8	25.50	3	31.25	2	58 25
2	25.25	4	30.35	3	51.25
5	24.00	5	23.50	7	48.65
1	23.00	8	22.65	8	48.15
3	20.00	7	21.90	5	47.50
6	18.75	6	21.50	6	40.20
9	14.00	9	19.35	9	33.35

SECTION **DD.—Barley.—**1871.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
4	4.180	4	13.570	4	17.750
6	3.790	6	10.310	6	14.100
2	3.450	2	9.650	2	13.100
9	3.090	3	9.170	3	12.000
8	2.922	8	8.678	8	11.600
3	2.830	5	8.488	5	11.250
5	2.762	1	8.185	9	10.750
1	2.315	7	7.943	1	10.500
7	2.307	9	7.660	7	10.250

SECTION **DD.—Beans.—**1871.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	4.530	4	5.020	4	9.550
5	2.030	2	4.350	5	6.250
2	1.050	5	4.220	2	5.400
8	1.015	3	4.010	3	4.450
6	0.950	1	3.875	6	4.350
9	0.910	6	3.400	1	4.250
3	0.440	8	2.835	8	3.850
1	0.375	9	2.790	9	3.700
7	0.245	7	2.355	7	2.600

The third set of tables, given below, are analogous to the preceding, but each of them includes the results obtained upon a pair of sections; i. e. upon one of the four main divisions of the field. The several crops are arranged as before in the order of excellence, from the best to the worst. It is to be remembered, however, that the conclusions drawn from comparisons between the different squares of a single section of the field (as in the second set of tables above) are naturally more to be depended upon than those based upon contrasts between the members of two sections, — i. e. of an entire division, — since it is not unlikely that the soil at one end of the long division may differ somewhat from the soil at the other end. The same reasoning would discourage the idea of combining too closely the results of different sections or divisions not absolutely contiguous, though it is plain that another set of tables, as good as the third set, might be constructed by combining the results of any two adjoining sections of the field, as, for example, B and C, or BB and CC. As a general rule, however, inferences based upon the order of excellence, as laid down in the second set of tables, will be stronger than those drawn from the tables of the third set, or from comparisons such as have just been suggested.

The following Tables show the Best and the Worst Crops obtained from each **Division** *of the Field.*

Barley.—1871.

Names and numbers of squares.	Weights of grain.	Names and numbers of squares.	Weights of straw.	Names and numbers of squares.	Weights of total crops.
A 9	8.540	A 2	24.575	A 2	32 10
A 3	8.055	A 3	23.695	A 3	31.75
A 8	8.000	A A 3	22 900	A 6	30.50
A 6	7.975	A 6	22 525	A 9	30.00
A A 9	7.570	A A 6	22 430	A 8	29.75
A 2	7.525	A 1	22.298	AA {3, 9}	29.60
A A 1	7.435	A A 9	22 030		
A 5	7.090	A 5	21.780	A 5	28.87
A 4	7.020	A 8	21.750	A A 6	28 25
A 7	6.807	A 9	21.460	A 4	27.87
A A 3	6.700	A A 2	21 200	A 1	27.50
A A 8	6.350	A 4	20.850	A A 2	26.50
A A 6	5.820	A A 5	19 938	A A 8	25.50
A A 2	5.300	A A 8	19.150	A 7	24.87
A 1	5.202	A A 4	18 088	A A 5	24.75
A A 7	5.190	A 7	18.063	AA {1, 4}	23.00
A A 4	4.912	A A 7	16.060		
A A 5	4.812	A A 1	15.565	A A 7	21.25
B B 1	5.145	B 1	18 530	B B 1	23.40
B B 4	4.725	B B 1	18.255	B 1	21.10
B B 7	4 630	B 2	16 160	B B 4	20.10
B B 2	4.000	B B 2	15.850	B B 2	19.85
B B 8	2.990	B B 4	15 375	B 2	18.75
B B 9	2.850	B B 7	13.870	B B 7	18.50
B B 3	2.680	B B 3	11 070	B B 3	13.75
B {2, 9}	2.590	B B 8	9.610	B B 8	12.60
		B 8	8.770	B 8	11.25
B 1	2 570	B 6	7 670	B B 9	10.10
B 8	2 480	B 9	7.410	B 9	10.00
B B 6	2 095	B B 9	7.250	B 6	9.75
B 6	2.080	B 4	7.180	B B 6	9.00
B 4	1.570	B B 6	6.905	B 4	8.75
B B 5	1.550	B B 5	4.950	B B 5	6 50
B 5	1.120	B 7	4.365	B 7	5.40
B 7	1.035	B 3	4.130	B 3	5.10
B 3	0.970	B 5	3.880	B 5	5.00

Beans.—1871.

Names and numbers of squares.	Weights of beans.	Names and numbers of squares.	Weights of straw.	Names and numbers of squares.	Weights of total crops.
A 2	11.300	A 2	10 950	A 2	22.250
A 1	10.425	A 3	10.830	A 3	21.000
A 3	10.150	A A 3	9 940	A 1	19.850
A A 2	9.655	A A 4	9.475	A A 3	18.950
A A 3	9.010	A 1	9.425	A A 2	18.750
A 4	8.960	A A 6	9.420	A A 4	17.550
A A 7	8.110	A A 8	9.130	A 4	17 250
A A 4	8.075	A A 2	9.095	A A 1	16 500
A A 5	7.715	A A 1	8.970	A A 7	16.350
A A 1	7.530	A A 9	8.845	A A 5	16.300
A 5	7.300	A A 5	8.585	A 5	15.450
A 7	7.210	A 4	8 290	A 7	15.250
A A 8	5.670	A A 7	8.240	A A 8	14 800
A A 9	4.155	A 5	8.150	A A 6	13.400
A 6	4 110	A 6	8.140	A A 9	13.000
A A 6	3.980	A 7	8.040	A 6	12 250
A 8	3 455	A 9	7.400	A 9	10.300
A 9	2.900	A 8	6.145	A 8	9.600
B 2	9.090	B B 1	10.035	B 2	18.150
B B 4	8.230	B B 2	9. 00	B B 2	16.850
B B 2	7.550	B 2	9.3	B 1	16.000
B 1	7.380	B B 3	9.050	B B 4	15.500
B B 7	7.230	B 1	8.620	B B 3	15.250
B B 6	6.605	BB {4, 7}	7.270	B B 1	15.100
B 8	6.255			B B 7	14.500
B B 3	6.200	B B 6	7.095	B B 6	13.700
B B 1	5.065	B 9	6.790	B 8	12 700
B 4	4.740	B 8	6.445	B 9	11.250
B 6	4.550	B 4	5.810	B 4	10.550
B 9	4.460	B 7	5.575	B 6	9.400
B B 8	4.020	B B 9	5.100	B 7	9.250
B 7	3.675	B 6	4.850	B B 8	8.600
B B 9	3.450	B B 8	4.580	B B 9	8.550
B B 5	2.450	B B 5	4.350	B B 5	6.800
B 3	0.935	B 5	3.185	B 3	4.000
B 5	0.565	B 3	3.065	B 5	3.750

Ruta-Bagas.—1871.

Names and numbers of squares.	Weights of roots.	Names and numbers of squares.	Weights of tops.	Names and numbers of squares.	Wei s of total crops.
A A 3	66.75	A A 3	46.85	A A 3	113.60
A 3	60.50	A A 9	44.25	A A 2	94.50
A A 2	59.75	A 7	40.00	A 3	93 85
A 2	54.75	A 8	38.10	AA {1, 9}	87.25
A 1	54 25	A 9	37.75		
A A 1	53.75	A A 7	35.55	A 2	86.50
A 5	52.25	A A 2	34.75	A 1	82.25
A 6	44.75	A A 1	33.50	A 5	82.00
A 8	43.25	A 3	33 25	A 7	81.75
A A 9	43 00	A A 8	31.90	A 8	81.35
A 7	41.75	A A 6	31.85	A 9	76.25
A A 6	39.75	A 2	31.75	A A 6	71.60
A A 5	39 40	A 5	29.75	A A 7	71.55
A A 4	39.00	A 1	28.00	A 6	68 50
A 9	38.50	A A 5	26 65	A A 8	66.65
A 4	37.25	A A 4	25.10	A A 5	66.05
A A 7	36.00	A 4	25 00	A A 4	64.10
A A 8	34.75	A 6	23.75	A 4	62.25
B B 1	81.00	B B 1	47.25	B B 1	128.25
B B 2	68.25	B B 2	45.50	B B 2	113 75
B 1	67.50	B 2	41 50	B 1	107.00
B B 4	63.75	B 1	39.50	B B 4	101.25
B 2	50.25	B B 4	37.50	B 2	91.75
B B 7	41.00	B B 7	32.00	B B 7	73 00
B B 6	34.50	B B 6	30.50	B B 6	65.00
B 8	32.25	B B 3	29.50	B 8	52 50
B 9	23.75	B B 8	29.25	B B 8	45 75
B 6	21.75	B B 9	26.00	B B 9	44.00
B 7	21 25	B 7	22.00	B 7	43 25
B 4	19.25	B 8	20.25	B B 3	42.75
B B 9	18.00	B 4	19 25	B 9	41 50
B B 8	16.50	{B 9, B B 5}	17.75	B 4	38 50
B B 3	13.25			B 6	36.50
B 3	7.00	B 6	14.75	B B 5	23 75
B B 5	6 00	B 3	13.50	B 3	20.50
B 5	2.75	B 5	8.25	B 5	11.00

Barley. — 1871.

Names and numbers of squares.	Weights of grain.	Names and numbers of squares.	Weights of straw.	Names and numbers of squares.	Weights of total crops.
C C 5	2.942	C C 9	12.768	C C 9	15.25
C C 8	2.747	C C 2	12.432	C C {2	14.40
C C 6	2.740	C C 8	11.653	8}	
C C 9	2.482	C C 4	11.525	C C {4	13.00
C C 2	1.968	C C 7	10.610	5}	
C 9	1.692	C C 5	10.058	C C 7	12.10
C C 3	1.581	C 2	9.935	C C 6	10.60
C C 7	1.490	C 3	9.633	C C 3	10.50
C C 4	1.475	C 6	9.145	C {2	10.40
C C 1	1.472	C C 3	8.919	9}	
C 6	0.955	C 9	8.708	C 3	10.25
C 7	0.852	C C 1	8.628	C 6}	10.10
C 8	0.762	C 4	8.407	C C 1}	
C 5	0.747	C C 6	7.860	C 4	9.00
C 3	0.617	C 1	7.200	C 7	7.50
C 4	0.593	C 5	6.653	C {1	7.40
C 2	0.465	C 7	6.648	5	
C 1	0.200	C 8	6.638	8}	
D D 4	4.180	D D 4	13.570	D D 4	17.75
D D 6	3.790	D D 6	10.310	D D 6	14.10
D D 2	3.450	D D 2	9.650	D D 2	13.10
D 7	3.305	D 3	9.588	D 8	12.60
D D 9	3.090	D 8	9.523	D 4	12.40
D 8	3.077	D 4	9.515	D 7	12.10
D D 8	2.922	D D 3	9.170	D D 3	12.00
D 4	2.885	D 7	8.795	D D 8	11.60
D D 3	2.830	D D 8	8.678	D D 5	11.25
D D 5	2.762	D D 5	8.488	D 3	11.10
D 9	2.357	D 2	8.310	D D 9	10.75
D D 1	2.315	D D 1	8.185	D 2}	10.50
D D 7	2.307	D D 7	7.943	D D 1}	
D 2	2.190	D D 9	7.660	D D 7	10.25
D 5	1.780	D 9	7.643	D 9	10.00
D 3	1.512	D 6	6.820	D 6	8.25
D 6	1.430	D 5	6.220	D 5	8.00
D 1	1.205	D 1	4.795	D 1	6.00

Beans. — 1871.

Names and numbers of squares.	Weights of beans.	Names and numbers of squares.	Weights of straw.	Names and numbers of squares.	Weights of total crops.
C C 7	3.860	C C 8	6.860	C C 7	10.650
C 4	3.575	C C 7	6.790	C C 8	10.100
C C 8	3.240	C 4	5.675	C 4	9.250
C 7	3.000	C 7	5.250	C 7	8.250
C C 2	2.265	C C 9	5.115	C C 2	7.050
C 1	2.185	C C 2	4.785	C C 9	6.950
C 8	2.020	C {3	4.375	C 1	6.100
C C 9	1.835	5}		C {5	5.950
C 5	1.575	C C 4	4.115	8}	
C 2	1.545	C 2	4.105	C 2	5.650
C C 3	1.290	C C 1	4.045	C 3	5.450
C 9	1.225	C C 5	3.970	C C 3	5.150
C 3	1.075	C 8	3.930	C 9}	5.100
C C 4	0.985	C 1	3.915	C C 4}	
C 6	0.840	C 9	3.875	C C 1	4.800
C C 1	0.755	C C 3	3.860	C C 5	4.700
C C 5	0.730	C C 6	3.585	C 6	4.400
C C 6	0.715	C 6	3.560	C C 6	4.300
D D 4	4.530	D D 4	5.020	D D 4	9.550
D 4	3.785	D 4	4.465	D 4	8.250
D 7	3.290	D 7	4.360	D 7	7.650
D D 5	2.030	D D 2	4.350	D D 5	6.250
D 6	1.415	D D 5	4.220	D D 2	5.400
D D 2	1.050	D D 3	4.010	D 6	5.100
D D 8	1.015	D D 1	3.875	D D 3	4.450
D D 6	0.950	D 1	3.825	D 1	4.400
D D 9	0.910	D 6	3.685	D D 6	4.350
D 9	0.720	D 3	3.515	D D 1	4.250
D 1	0.575	D D 6	3.400	D 3}	3.850
D 8	0.470	D 2	3.185	D D 8}	
D 5	0.455	D 8	3.130	D D 9	3.700
D D 3	0.440	D D 8	2.835	D {8	3.600
D 2	0.415	D D 9	2.790	2}	
D D 1	0.375	D 5	2.645	D 9	3.350
D 3	0.335	D 9	2.630	D 5	3.100
D D 7	0.245	D D 7	2.355	D D 7	2.600

Ruta-Bagas. — 1871.

Names and numbers of squares.	Weights of roots.	Names and numbers of squares.	Weights of tops.	Names and numbers of squares.	Weights of total crops.
C 3	35.25	C C 9	23.00	C 3	55.50
C 2	25.75	C C 2	22.00	C C 1	45.00
C C 5	24.75	C C 1	21.25	C C 2	44.50
C C 1	23.75	C 8	21.00	C C 5	41.00
C C 2	22.50	C C 8	20.50	C {2	39.75
C C 4	21.00	C 3	20.25	7}	
C 7	19.75	C 7	20.00	C C 4	38.25
C C 7	17.50	C 4	19.00	C C 7	34.50
C 9	13.25	C 9	18.25	C 8	33.75
C C 8	13.00	C C 3	18.00	C C 8	33.50
C {4	12.75	C C 4	17.25	C C 9	32.75
8}		C C 7	17.00	C 4	31.75
C 1	12.25	C C 5	16.25	C 9	31.50
C C 6	10.75	C {2	14.00	C C 3	26.25
C 6	10.50	6		C C 6	24.75
C C 9	9.75	C C 6}		C 6	24.50
C 5	9.25	C 5	13.00	C 1	23.00
C C 3	8.25	C 1	10.75	C 5	22.25
D D 4	35.75	D D 1	35.75	D D 4	66.10
D 5	34.50	D D 2	33.00	D D 1	58.75
D 6	28.25	D D 3	31.25	D D 2	58.25
D D 7	26.75	D D 4	30.35	D D 3	51.25
D D 8	25.50	D D 5	23.50	D D 7	48.65
D 7}	25.25	D D 8	22.65	D D 8	48.15
D D 2}		D D 7	21.90	D D 5	47.50
D 2}	24.00	D D 6	21.50	D 6	46.50
D D 5}		D 3	21.25	D 5	43.75
D {4	23.25	D 1	20.50	D 2	43.25
9}		D D 9	19.35	D D 6	40.20
D D 1	23.00	D 2	19.25	D 7	39.75
D D 3	20.00	D 6	18.25	D 3	35.75
D D 6	18.75	D 7	14.50	D 9	34.25
D 8	17.75	D 9	11.00	D D 9	33.35
D 3	14.50	D 4	10.00	D 4	33.25
D D 9	14.00	D 5	9.25	D 1	31.75
D 1	11.25	D 8	6.50	D 8	24.25

The results of this first year's trials are decidedly favorable in the case of the potassic manures. Sulphate of potash, for example (a pure article, commercially speaking), applied at the rate of 800 lbs. to the acre, gave 2,577 lbs., i. e. 43 bushels, of beans to the acre, or three times as many as were harvested from the unmanured land. Barley thus heavily dressed with sulphate of potash yielded at the rate of 1,650 lbs. or 34 bushels of grain to the acre, or more than twice as much as was got from the unmanured land.

Some of the results obtained by the use of lime upon land that had been previously manured (Section A) are remarkable. In several instances the squares yielded barley at the rate of 2,850 lbs., or 59 bushels to the acre.

No. 6. — *A Record of Trials of various Fertilizers upon the Plain-field of the Bussey Institution.* By F. H. Storer. *Second Report.** *Results obtained in* 1872.

With the exception of a few trifling points of detail, the experiments of 1872 were exact repetitions of those of 1871. (See pages 80 to 102 of this Bulletin.) The same kinds of crops were grown as before, and the same kinds and amounts of fertilizers were applied to each of the squares of land; that is to say, the same kinds of materials as those used last year were again purchased of the same dealers. Naturally enough, some of them differed a little in composition from the previous samples, as may be seen from the analyses reported on pages 8 to 12 of this Bulletin. As a matter of course, the land had to be spaded this year, since a plough would have disturbed the stakes by which the squares were marked.

The fertilizers were applied and the seeds sown in the same ways as before, with the exception that the barley, instead of being strewn broadcast, was now sown in little drills, 33 centimetres apart, in order that it might be thoroughly covered with soil, to protect it from the depredations of birds.

The summer of 1872 was remarkable for an almost constant succession of severe thunder-showers, which greatly injured the experimental crops. The soil of the field, resting upon loose gravel, as explained on page 80, was continually leached by large volumes of rain-water, to the manifest detriment of the crops. The surface of the land was often muddy, and at other times crusted. The bean crop suffered very much from dirt that was spattered upon it by the frequent heavy rains. Not only was the growth of the plants hindered in this way, but many leaves that dried up prematurely, because of injuries caused by the particles of dirt, were blown away before the time of harvesting, and so lost altogether. In general it appeared that the less food the plants had the more the crop suffered from this cause. The beans could not be hoed so frequently as in the previous year, because of the muddy condition of the land.

* Presented to the Trustees of the Massachusetts Society for Promoting Agriculture, March 28, 1873.

The barley crop seemed to suffer also, in many instances, from dirt thus spattered upon it, as well as from the frequent wettings to which it was subjected. The well-known objection to growing any grain crop continuously upon old land filled with the seeds of weeds was conspicuously exhibited during the latter part of this season. Naturally enough, during the term of frequent showers many weeds grew upon all the barley plots, particularly upon those to which farm or stable manure had been applied. Since it would have been impossible to remove these weeds without disturbing some of the barley plants, and so destroying the comparative value of the experiments, they were, of course, left undisturbed until the time of harvest. It should be understood that, with the exception perhaps of the plots dressed with dung, all the barley crops were equally affected by the plague of weeds, and that consequently the comparative value of the results obtained was little, if at all, influenced by this cause. Indeed, I saw no reason for believing that even the absolute yield of either of the crops had been lessened to any material extent by the presence of the weeds. For that matter, the weeds were neither very vigorous nor very abundant until after the barley had arrived at a stage of growth when the fate of each particular crop was as good as settled. In comparison with the inclement weather to which the barley was exposed, and the insufficient supplies of food that were given it, the weeds were but a trifling encumbrance.

The ruta-baga crop was practically a total failure, owing to the use of bad seed (obtained from a dealer of excellent repute).* Since the badness of the seed would be likely to affect all parts of the field alike, the crops harvested from the several squares were all weighed, and the results are tabulated below; but, as was the case with the dried-up crop of 1871, very little importance is to be attached to the results obtained with this plant.

The weights, in kilogrammes, of fertilizers used and of crops harvested, will appear from the following tables.

* In a special experiment made in the laboratory subsequent to the planting, to test this seed, a large proportion of it failed to germinate.

Section A. — Kinds and Weights of Crops, in Kilogrammes. 1872.

Weights of fertilizers, in kilogrammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
13.65 kilos. of spent gas-lime	1	1.83	7 32	9.15	7.51	5.39	12.90	20.00	14.50	34.50
13.65 kilos. of oyster-shell flour *	2	1.45	6.55	8.00	10.27	5.73	16.00	22.00	21.00	43.00
13.65 kilos. of lime from oyster-shells	3	2 45	9.05	11.50	8.22	6.18	14.40	13.25	15.50	28.75
15 kilos. of spent soap-boiler's lime	4	1 75	7.10	8.85	7.29	4.06	11.35	11.50	10.00	21.50
No manure	5	1 64	8.01	9.65	3.95	2.80	6.75	11.75	12.00	23.75
13.65 kilos. of Rockland lime	6	1.65	7.85	9.50	5.27	4.03	9.30	17.75	18.25	36.00
0.307 kilos. of common salt and 13.65 kilos. lime from oyster-shells	7	2.25	6.40	8.65	5.37	3.13	8.50	18.00	13.65	31.65
13.65 kilos. of gypsum	8	2.13	7 22	9.35	3.78	2.32	6.10	17.00	13.75	30.75
13.65 kilos. of Brandon lime	9	1.60	6.15	7.75	4.52	3.28	7.80	17.00	16.85	33.85

Section AA. — Kinds and Weights of Crops. 1872.

All the plots were manured precisely like those in A, with the addition of 8 cubic feet of peat to each plot.	1	2.48	7.52	10.00	7.16	5.04	12.20	11.75	12.25	24.00
	2 †	2.05	6.70	8.75	7.43	4.87	12.30	12.50	10.75	23.25
	3	2.32	7.18	9.50	7.30	4.75	12.05	12.50	10.25	22.75
	4	1.27	4.73	6.00	7.23	3.67	10.90	9.75	9.75	19.50
	5	1.14	5.36	6.50	6.62	3.88	10.50	11.25	9.25	21.50
	6	2.05	7.60	9.65	5.51	3.49	9.00	8.50	16.50	25.00
	7	1.76	6.74	8.50	5.93	3.72	9.65	23.75	16.50	40.25
	8	1.46	7.04	8.50	5.43	3.32	8.75	16.75	11.25	28.00
	9	2.07	7.93	10.00	5.10	3.00	8.10	17.50	13.75	31.25

* The supply of oyster-shell flour gave out after the barley and bean plots had been dressed The ruta-bagas on square No. 2 got none of it this year.
† The barley square AA 2 was dressed with oyster-shell flour, but neither the beans nor the ruta-bagas got any.

Section B. — Kinds and Weights of Crops, in Kilogrammes. 1872.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
8 cubic feet of farm-manure from Mr. Motley *	1	1.65	7.60	9.25	6.41	6.34	12.75	15.00	7.50	22.50
8 cubic feet of long horse-manure †	2	0.97	4.03	5.00	5.60	?	7.25+	31.00	25.00	56.00
972 grms. of fish-scrap	3	0.80	3.20	4.00	0.93	1.17	2.10	10.25	17.50	27.75
4095 grms. of wood-ashes	4	0.80	4.20	5.00	5.44	3.66	9.10	9.00	8.75	17.75
No manure	5	0.75	3.50	4.25	0.66	0.99	1.65	2.75	7.25	10.00
307 grms. of pearl-ash	6	1.76	7.24	9.00	4.05	2.60	6.65	20.00	15.75	35.75
307 grms. of sulphate of potash	7	1.24	2.61	3.85	4.66	2.94	7.60	11.25	10.25	21.50
307 grms. of sulphate of ammonia	8	0.60	6.40	7.00	4.29	3.21	7.50	15.00	12.50	27.50
4095 grms. of New Jersey green sand	9	1.56	5.59	7.15	3.55	2.70	6.25	6.25	7.50	13.75

Section BB. — Kinds and Weights of Crops. 1872.

Weights of fertilizers, in grammes.	Nos. of the squares.	Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
8 cubic feet of farm-manure from Mr. Motley *	1	2.76	9.89	12.65	4.46	3.79	8.25	22.25	17.25	39.50
8 cubic feet of long horse-manure †	2	2.41	7.94	10.35	4.58	3.42	8.00	5.75	4.50	10.25
2916 grms. of fish-scrap	3	2.10	8.15	10.25	4.24	3.46	7.70	2.25	2.50	4.75
3 bushels of wood-ashes	4	2.86	10.14	13.00	6.32	4.68	11.00	12.00	9.00	21.00
No manure	5	1.31	4.54	5.85	1.58	1.82	3.40	2.50	4.00	6.50
1336 grms. of pearl-ash	6	2.11	4.89	7.00	5.19	3.61	8.80	6.25	5.25	11.50
2267 grms. of sulphate of potash	7	2.65	8.20	10.85	5.76	3.74	9.50	1.25	2.00	3.25
4987 grms. of sulphate of ammonia	8	1.05	5 10	6.15	2.25	1.65	3.90	1.50	4.50	6.10
8190 grms. of New Jersey green sand	9	1.50	5.65	7.15	2.65	2.50	5.15	5.50	6.25	11.75

* The farm-manure contained this year a large proportion of undecomposed leaves of forest hard-wood trees.

† The quality of the stable-manure was decidedly inferior to that of the previous year. Last year the material consisted of a mixture of dung and straw; this year there was no straw, but an excessively large proportion of *sedge*, i. e. of bog hay.

Section C. — Kinds and Weights of Crops, in Kilogrammes. 1872.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
1365 grms. of a mixture of Bradley's and Breck's bone-meal *	1	0.71	3.44	4.15	0.24	0.76	1.00	8.00	13.75	21.75
972 grms. of Peruvian guano	2	0.90	4.35	5.25	0.90	1.10	2.00	15.00	16.00	31.00
1365 grms. of Wilson's superphosphate	3	1.24	4.41	5.65	0.29	0.71	1 00	9.00	12.50	21.50
1638 grms. of crushed bone	4	0.52	2.83	3.35	1.60	1.40	3.00	3.50	11.50	15.00
No manure	5	0.76	3.09	3.85	0.34	0.16	0.50	5.00	7.75	12.75
No manure, in lack of floated bone † .	6	1.07	4.58	5.65	0 29	0.71	1.00	7.00	17.50	24.50
1365 grms. of Bay State superphosphate	7	0.87	3.88	4.75			0.65	6.50	17.50	24.10
1365 grms. of Coe's superphosphate .	8	0.88	3.87	4 75	0.34	0.81	1.15	9.25	14.50	23.75
1365 grms. of Bradley's "X L" superphosphate	9	1.45	5.40	6.85	0.26	0.59	0.85	5.25	14.25	19.50

Section CC. — Kinds and Weights of Crops. 1872.

Weights of fertilizers, in grammes.	Nos. of the squares.	Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
1869 grms. of Bradley's bone-meal .	1	1.30	4.95	6.25	0.15	0.60	0.75	7.50	12 50	20.00
1068 grms. of Peruvian guano . . .	2	1.61	5.89	7.50	0.65	1.00	1.65	5.50	9.50	15.00
1485 grms. of Wilson's superphosphate	3	0.72	3.53	4.25	0.15	0.75	0.90	1.75	6.25	8.00
1365 grms. of Breck's flour of bone .	4	0.88	3.47	4.35	0.05	0.75	0.80	11.00	12.50	23 50
No manure	5	1.06	4.59	5.65	0.21	0.79	1.00	3.75	4.25	8.00
No manure, in lack of floated bone † .	6	0 92	3.33	4.25	0.09	0.81	0 90	4.75	8.25	13.00
1365 grms. Bay State superphosphate .	7	1.05	4.20	5.25	2.23	2.27	4.50	11.25	12.25	23.50
1450 grms. of Coe's superphosphate .	8	1.61	6.24	7.85	1.48	1.82	3.30	3.25	7.50	10.75
1365 grms. of "X L" superphosphate	9	2.13	7.37	9.50	0.53	1.07	1.60	2.50	7.00	9.50

* The ruta-bagas got Bradley's bone-meal alone.

† None of the floated bone could be procured this year.

Section D. — Kinds and Weights of Crops, in Kilogrammes. 1872.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
144.5 grms. of nitrate of ammonia . .	1	1.36	4.99	6.35	0.16	0.59	0.75	3.00	7.50	10.50
307 grms. of nitrate of soda	2	0.71	4.44	5.15	0.06	0.59	0.65	7.00	8.00	15.00
238.33 grms. of sulphate of ammonia .	3	1.29	4.21	5.50	0.10	0.55	0.65	4.50	9.75	14.25
238.33 grms. of sulphate of ammonia plus 314.5 grms. of sulphate of potash	4	2.03	6.97	9.00	3.18	2.32	5.50	10.25	6.75	17.00
No manure	5	0.97	4.03	5.00	0.14	0.76	0.90	7.25	7.00	14.25
193 grms. of chloride of ammonium .	6	1.24	4.01	5.25	0.59	1.06	1.65	4.50	9.00	13.50
365 grms. of nitrate of potash . . .	7	2.37	8.38	10.75	2.29	1.71	4.00	14.50	8.25	22.75
238.33 grms. of sulphate of ammonia plus 581.5 grms. of sulphate of soda	8	2.09	6.76	8.85	0.25	0.45	0.70	9.75	7.25	17.00
213 grms. of carbonate of ammonia .	9	0.93	3.42	4.35	0.15	0.70	0.85	5.75	10.25	16.00

Section DD. — Kinds and Weights of Crops. 1872.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley: Grain.	Barley: Straw and chaff.	Barley: Total product.	Beans: Beans.	Beans: Stalks, leaves, and husks.	Beans: Total product.	Ruta-Bagas: Roots.	Ruta-Bagas: Tops.	Ruta-Bagas: Total product.
307 grms. of nitrate of soda	1	1.09	4.16	5.25	0.03	0.62	0.65	4.75	9.00	13.75
307 grms. of roasted salt-cake . . .	2	1.92	6.73	8 65	0.31	0.94	1.25	6.25	10.75	17.00
307 grms. of silicate of soda	3	1.53	4.72	6.25	0.21	0.99	1.20	2.00	3.25	5.25
307 grms. of nitrate of potash . . .	4	2.03	6.72	8.75	1.78	1.57	3.35	9.75	9.25	19.00
No manure	5	1.50	5.50	7.00	0.49	0.91	1.40	3.00	5.25	8.25
154 grms. of common salt	6	1.42	4.58	6.00	0.42	0.88	1.30	2.25	2.50	4.75
307 grms. of cotton-seed meal . . .	7	1.23	4.02	5.25	0.10	0.50	0.60	9.25	6.50	15.75
2730 grms. of flocks	8	1.13	3.62	4.75	0.14	0.56	0.70	2.75	2.25	5.00
2730 grms. of leather-parings . . .	9	0.77	2.73	3.50	0.18	0.52	0.70	2.50	1.50	4.00

SECTION **A.—Barley.**—1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
3	2.45	3	9.05	3	11.50
7	2.25	5	8.01	5	9.65
8	2.13	6	7.85	6	9.50
1	1.83	1	7.32	8	9.35
4	1.75	8	7.22	1	9.15
6	1.65	4	7.10	4	8.85
5	1.64	2	6.55	7	8.65
9	1.60	7	6.40	2	8.00
2	1.45	9	6.15	9	7.75

SECTION **A.—Beans.**—1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	10.27	3	6.18	2	16.00
3	8.22	2	5.73	3	14.40
1	7.51	1	5.39	1	12.90
4	7.29	4	4.06	4	11.35
7	5.37	6	4.03	6	9.30
6	5.27	9	3.28	7	8.50
9	4.52	7	3.13	9	7.80
5	3.95	5	2.80	5	6.75
8	3.78	8	2.32	8	6.10

SECTION **A.—Ruta-Bagas.**—1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
2	22.00	2	21.00	2	43.00
1	20.00	6	18.00	6	36.00
7	18.00	9	16.85	1	34.50
6	17.75	3	15.50	9	33.85
8	17.00	1	14.50	7	31.65
9		8	13.75	8	30.75
3	13.25	7	13.65	3	28.75
5	11.75	5	12.00	5	23.75
4	11.50	4	10.00	4	21.50

SECTION **AA.—Ruta-Bagas.**—1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
7	23.75	6	16.50	7	40.25
9	17.50	7		9	31.25
8	16.75	9	13.75	8	28.00
2	12.50	1	12.25	6	25.00
3		8	11.25	1	24.00
1	11.75	2	10.75	2	23.25
5	11.25	3	10.25	3	22.75
4	9.75	4	9.75	5	21.50
6	8.50	5	9.25	4	19.50

SECTION **AA.—Barley.**—1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
1	2.48	9	7.93	9	10.00
3	2.32	6	7.60	1	
9	2.07	1	7.52	6	9.65
6	2.05	3	7.18	3	9.50
2		8	7.04	2	8.75
7	1.76	7	6.74	7	8.50
8	1.46	2	6.70	8	
4	1.27	5	5.36	5	6.50
5	1.14	4	4.73	4	6.00

SECTION **AA.—Beans.**—1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	7.43	1	5.04	2	12.30
3	7.30	2	4.87	1	12.20
4	7.23	3	4.75	3	12.05
1	7.16	5	3.88	4	10.90
5	6.62	7	3.72	5	10.50
7	5.93	4	3.67	7	9.65
6	5.51	6	3.49	6	9.00
8	5.43	8	3.32	8	8.75
9	5.10	9	3.00	9	8.10

SECTION **B.—Barley.**—1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
6	1.76	1	7.60	1	9.25
1	1.65	6	7.24	6	9.00
9	1.56	8	6.40	9	7.15
7	1.24	9	5.59	8	7.00
2	0.97	4	4.20	2 }	5.00
3 }	0.80	2	4.03	4 }	
4 }		5	3.50	5	4.25
5	0.75	3	3.20	3	4.00
8	0.60	7	2.61	7	3.85

SECTION **B.—Beans.**—1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
1	6.41	1	6.34	1	12.75
2	5.60	4	3 66	4	9.10
4	5.44	8	3.21	7	7.60
7	4.66	7	2.94	8	7.50
8	4.29	9	2.70	2	7.25
6	4 05	6	2.60	6	6.65
9	3 55	3	1.17	9	6.25
3	0.93	5	0.99	3	2.10
5	0.66			5	1.65

SECTION **B.—Ruta-Bagas.**—1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
2	31.00	2	25.00	2	56.00
6	20.00	3	17.50	6	35.75
1 }	15.00	6	15.75	3	27.75
8 }		8	12.50	8	27.50
7	11.25	7	10.25	1	22.50
3	10.25	4	8.75	7	21.50
4	9.00	1 }	7.50	4	17.75
9	6.25	9 }		9	13.75
5	2.75	5	7.25	5	10.00

SECTION **BB.—Ruta-Bagas.**—1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
1	22.25	1	17.25	1	39.50
4	12.00	4	9.00	4	21.00
6	6.25	9	6.25	9	11.75
2	5.75	6	5.25	6	11.50
9	5.50	2 }	4.50	2	10.25
5	2.50	8 }		5	6.50
3	2.25	5	4.00	8	6.10
8	1.50	3	2.50	3	4.75
7	1.25	7	2.00	7	3.25

SECTION **BB.—Barley.**—1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
4	2.86	4	10.14	4	13.00
1	2.76	1	9.89	1	12.65
7	2.65	7	8.20	7	10.85
2	2.41	3	8.15	2	10.35
6	2.11	2	7.94	3	10.25
3	2.10	9	5.65	9	7.15
9	1.50	8	5.10	6	7.00
5	1.31	6	4.89	8	6.15
8	1.05	5	4.54	5	5.85

SECTION **BB.—Beans.**—1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	6.32	4	4.68	4	11.00
7	5.76	1	3.79	7	9.50
6	5.19	7	3.74	6	8.80
2	4.58	6	3.61	1	8 25
1	4.46	3	3.46	2	8.00
3	4.24	2	3.42	3	7.70
9	2.65	9	2.50	9	5.15
8	2.25	5	1.82	8	3.90
5	1.58	8	1.65	5	3.40

SECTION **C. — Barley. —** 1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
9	1.45	9	5.40	9	6.85
3	1.24	6	4.58	3, 6	5.65
6	1.07	3	4.41	2	5.25
2	0.90	2	4.35	7, 8	4.75
8	0.88	7	3.88	1	4.15
7	0.87	8	3.87	5	3.85
5	0.76	1	3.44	4	3.35
1	0.71	5	3.09		
4	0.52	4	2.83		

SECTION **C. — Beans. —** 1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	1.60	4	1.40	4	3.00
2	0.90	2	1.10	2	2.00
5, 8	0.34	8	0.81	8	1.15
3, 6	0.29	1	0.76	1, [illegible], [illegible]	1.00
9	0.26	3, 6	0.71	9	0.85
1	0.24	9	0.59	7	0.65
		5	0.16	5	0.50

SECTION **C. — Ruta-Bagas. —** 1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
2	15.00	6, 7	17.50	2	31.00
8	9.25	2	16.00	6	24.50
3	9.00	8	14.50	7	24.10
1	8.00	9	14.25	8	23.75
6	7.00	1	13.75	1	21.75
7	6.50	3	12.50	3	21.50
9	5.25	4	11.50	9	19.50
5	5.00	5	7.75	4	15.00
4	3.50			5	12.75

SECTION **CC. — Ruta-Bagas. —** 1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
7	11.25	1, 4	12.50	4, 7	23.50
4	11.00	7	12.25	1	20.00
1	7.50	2	9.50	2	15.00
2	5.50	6	8.25	6	13.00
6	4.75	8	7.50	8	10.75
5	3.75	9	7.00	9	9.50
8	3.25	3	6.25	3, 5	8.00
9	2.50	5	4.25		
3	1.75				

SECTION **CC. — Barley. —** 1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
9	2.13	9	7.37	9	9.50
2, 8	1.61	8	6.24	8	7.85
1	1.30	2	5.89	2	7.50
5	1.06	1	4.95	1	6.25
7	1.05	5	4.59	5	5.65
6	0.92	7	4.20	7	5.25
4	0.88	3	3.53	4	4.35
3	0.72	4	3.47	3, 6	4.25
		6	3.33		

SECTION **CC. — Beans. —** 1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
7	2.23	7	2.27	7	4.50
8	1.48	8	1.82	8	3.30
2	0.65	9	1.07	2	1.65
9	0.53	2	1.00	9	1.60
5	0.21	6	0.81	5	1.00
1, 3	0.15	5	0.79	3, 6	0.90
6	0.09	3, 4	0.75	4	0.80
4	0.05	1	0.60	1	0.75

SECTION **D. — Barley.** — 1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
7	2.37	7	8.38	7	10.75
8	2.09	4	6.97	4	9.00
4	2.03	8	6.76	8	8.85
1	1.36	1	4.99	1	6.35
3	1.29	2	4.44	3	5.50
6	1.24	3	4.21	6	5.25
5	0.97	5	4.03	2	5.15
9	0.93	6	4.01	5	5.00
2	0.71	9	3.42	9	4.35

SECTION **D. — Beans.** — 1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	3.18	4	2.32	4	5.50
7	2.29	7	1.71	7	4.00
6	0.59	6	1.06	6	1.65
8	0.25	5	0.76	5	0.90
1	0.16	9	0.70	9	0.85
9	0.15	1 }	0.59	1	0.75
5	0.14	2 }		8	0.70
3	0.10	3	0.55	2 }	0.65
2	0.06	8	0.45	3 }	

SECTION **D. — Ruta-Bagas.** — 1872.

Nos. of the squares.	Weights of ruta-baga crops.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
7	14.50	9	10.25	7	22.75
4	10.25	3	9.75	4 }	17.00
8	9.75	6	9.00	8 }	
5	7.25	7	8.25	9	16.00
2	7.00	2	8.00	2	15.00
9	5.75	1	7.50	3 }	14.25
3 }	4.50	8	7.25	5 }	
6 }		5	7.00	6	13.50
1	3.00	4	6.75	1	10.50

SECTION **DD. — Ruta-Bagas.** — 1872.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
4	9.75	2	10.75	4	19.00
7	9.25	4	9.25	2	17.00
2	6.25	1	9.00	7	15.75
1	4.75	7	6.50	1	13.75
5	3.00	5	5.25	5	8.25
8	2.75	3	3.25	3	5.25
9	2.50	6	2.50	8	5.00
6	2.25	8	2.25	6	4.75
3	2.00	9	1.50	9	4.00

SECTION **DD. — Barley.** — 1872.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
4	2.03	2	6.73	4	8.75
2	1.92	4	6.72	2	8.65
3	1.53	5	5.50	5	7.00
5	1.50	3	4.72	3	6.25
6	1.42	6	4.58	6	6.00
7	1.23	1	4.16	1 }	5.25
8	1.13	7	4.02	7 }	
1	1.09	8	3.62	8	4.75
9	0.77	9	2.73	9	3.50

SECTION **DD. — Beans.** — 1872.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	1.78	4	1.57	4	3.35
5	0.49	3	0.99	5	1.40
6	0.42	2	0.94	6	1.30
2	0.31	5	0.91	2	1.25
3	0.21	6	0.88	3	1.20
9	0.18	1	0.62	8 }	0.70
8	0.14	8	0.56	9 }	
7	0.10	9	0.52	1	0.65
1	0.03	7	0.50	7	0.60

The following Tables show the Best and the Worst Crops obtained from each **Division** *of the Field.*

Barley.—1872.

Names and numbers of squares.	Weights of grain.	Names and numbers of squares.	Weights of straw and chaff.	Names and numbers of squares.	Weights of total crops.
A A 1	2.48	A 3	9.05	A 3	11 50
A 3	2.45	A 5	8.01	AA {9, 1}	10,00
A A 3	2.32	A A 9	7.93		
A 7	2.25	A 6	7.85	A 5 / A A 6	9.65
A 8	2.13	A A 6	7.60		
A A 9	2 07	A A 1	7.52	A 6 / A A 3	9.50
AA {6, 2}	2 05	A 1	7.32		
		A 8	7.22	A 8	9.35
A 1	1.83	A A 3	7.18	A 1	9.15
A A 7	1.76	A 4	7.10	A 4	8.85
A 4	1.75	A A 8	7.04	A A 2	8.75
A 6	1.65	A A 7	6.74	A 7	8.65
A 5	1.64	A A 2	6.70	AA {7, 8}	8.50
A 9	1.60	A 2	6.55		
A A 8	1.46	A 7	6 40	A 2	8.00
A 2	1.45	A 9	6.15	A 9	7.75
A A 4	1.27	A A 5	5.36	A A 5	6.50
A A 5	1.14	A A 4	4.73	A A 4	6.00
B B 4	2 86	B B 4	10.14	B B 4	13.00
B B 1	2.76	B B 1	9.89	B B 1	12.65
B B 7	2.65	B B 7	8.20	B B 7	10.85
B B 2	2.41	B B 3	8.15	B B 2	10.35
B B 6	2.11	B B 2	7.94	B B 3	10.25
B B 3	2.10	B 1	7.60	B 1	9.25
B 6	1.76	B 6	7.24	B 6	9.00
B 1	1.65	B 8	6.40	B { } / BB { }	7.15
B 9	1.56	B B 9	5.65		
B B 9	1.50	B 9	5.59	B 8 / B B 6	7.00
B B 5	1.31	B B 8	5.10		
B 7	1.24	B B 6	4.89	B B 8	6.15
B B 8	1.05	B B 5	4.54	B B 5	5.85
B 2	0.97	B 4	4.20	B 2 / B 4	5.00
B {3, 4}	0.80	B 2	4.03		
		B 5	3.50	B 5	4.25
B 5	0.75	B 3	3.20	B 3	4.00
B 8	0.60	B 7	2.61	B 7	3.85

Beans.—1872.

Names and numbers of squares.	Weights of beans.	Names and numbers of squares.	Weights of stalks and husks.	Names and numbers of squares.	Weights of total crops.
A 2	10.27	A 3	6.18	A 2	16.00
A 3	8.22	A 2	5.73	A 3	14.00
A 1	7.51	A 1	5.39	A 1	12.90
A A 2	7.43	A A 1	5.04	A A 2	12.30
A A 3	7.30	A A 2	4.87	A A 1	12.20
A 4	7.29	A A 3	4.75	A A 3	12.05
A A 4	7.23	A 4	4.06	A 4	11.35
A A 1	7.16	A 6	4.03	A A 4	10.90
A A 5	6.62	A A 5	3.88	A A 5	10.50
A A 7	5.93	A A 7	3.72	A A 7	9.65
A A 6	5.51	A A 4	3.67	A 6	9.30
A A 8	5.43	A A 6	3.49	A A 6	9.00
A 7	5.37	A A 8	3.32	A A 8	8.75
A 6	5 27	A 9	3.28	A 7	8.50
A A 9	5.10	A 7	3.13	A A 9	8.10
A 9	4.52	A A 9	3.00	A 9	7.80
A 5	3.95	A 5	2.80	A 5	6.75
A 8	3.78	A 8	2.32	A 8	6.10
B 1	6.41	B 1	6.34	B 1	12.75
B B 4	6.32	B B 4	4.68	B B 4	11.00
B B 7	5.76	B B 1	3.79	B B 7	9.50
B 2	5.60	B B 7	3.74	B 4	9.10
B 4	5.44	B 4	3.66	B B 6	8.80
B B 6	5.19	B B 6	3.61	B B 1	8.25
B 7	4.66	B B 3	3.46	B B 2	8.00
B B 2	4.58	B B 2	3.42	B B 3	7.70
B B 1	4.46	B 8	3.21	B 7	7.60
B 8	4.29	B 7	2.94	B 8	7.50
B B 3	4.24	B 9	2.70	B 2	7.25
B 6	4.05	B 6	2.60	B 6	6.65
B 9	3.55	B B 9	2.50	B 9	6.25
B B 9	2.65	B B 5	1.82	B B 9	5.15
B B 8	2.25	B B 8	1.65	B B 8	3.90
B B 5	1.58	B 3	1.17	B B 5	3.40
B 3	0.93	B 5	0.99	B 3	2.10
B 5	0.66			B 5	1.65

Ruta-Bagas.—1872.

Names and numbers of squares.	Weights of roots.	Names and numbers of squares.	Weights of tops.	Names and numbers of squares.	Weig'its of total crops.
A A 7	23.75	A 2	21.00	A 2	43.00
A 2	22.00	A 6	18.00	A A 7	40.25
A 1	20.00	A 9	16.85	A 6	36.00
A 7	18.00	AA {6, 7}	16.50	A 1	34.50
A 6	17.75			A 9	33.85
A A 9	17.50	A 3	15.50	A 7	31.65
A {8, 9}	17.00	A 1	14.50	A A 9	31.25
		A 8 / A A 9	13.75	A 8	30.75
A A 8	16.75			A 3	28.75
A 3	13.25	A 7	13.65	A A 8	28.00
AA {2, 3}	12.50	A A 1	12.25	A A 6	25.00
		A 5	12.00	A A 1	24.00
A 5 / A A 1	11.75	A A 8	11.25	A 5	23.75
		A A 2	10.75	A A 2	23.25
A 4	11.50	A A 3	10.25	A A 3	22.75
A A 5	11.25	A 4	10.00	A 4 / A A 5	21.50
A A 4	9.75	A A 4	9.75		
A A 6	8.50	A A 5	9.25	A A 4	19.50
B 2	31.00	B 2	25.00	B 2	56.00
B B 1	22.25	B 3	17.50	B B 1	39.50
B 6	20.00	B B 1	17.25	B 6	35.75
B {1, 8}	15.00	B 6	15.75	B 3	27.75
		B 8	12.50	B 8	27 50
B B 4	12.00	B 7	10.25	B 1	22.50
B 7	11.25	B B 4	9.00	B 7	21 50
B 3	10.25	B 4	8.75	B B 4	21.00
B 4	9.00	B {1, 9}	7.50	B 4	17.75
B 9 / B B 6	6.25			B 9	13 75
		B 5	7.25	B B 9	11.75
B B 2	5.75	B B 9	6.25	B B 6	11.50
B B 9	5.50	B B 6	5.25	B B 2	10.25
B 5	2.75	BB {2, 8}	4.50	B 5	10.00
B B 5	2.50			B B 5	6.50
B B 3	2.25	B B 5	4.00	B B 8	6.10
B B 8	1.50	B B 3	2.50	B B 3	4.75
B B 7	1.25	B B 7	2.00	B B 7	3.25

Barley. — 1872.

Names and numbers of squares.	Weights of grain.
C C 9	2.13
C C {2, 8}	1.61
C 9	1.45
C C 1	1.30
C 3	1.24
C 6	1.07
C C 5	1.06
C C 7	1.05
C C 6	0.92
C 2	0.90
C 8, C C 4	0.88
C 7	0.87
C 5	0.76
C C 3	0.72
C 1	0.71
C 4	0.52
D 7	2.37
D 8	2.09
D 4, D D 4	2.03
D D 2	1.92
D D 3	1.53
D D 5	1.50
D D 6	1.42
D 1	1.36
D 3	1.29
D 6	1.24
D D 7	1.23
D D 8	1.13
D D 1	1.09
D 5	0.97
D 9	0.93
D D 9	0.77
D 2	0.71

Names and numbers of squares.	Weights of straw and chaff.
C C 9	7.37
C C 8	6.24
C C 2	5.89
C 9	5.40
C C 1	4.95
C C 5	4.59
C 6	4.58
C 3	4.41
C 2	4.35
C C 7	4.20
C 7	3.88
C 8	3.87
C C 3	3.53
C C 4	3.47
C 1	3.44
C C 6	3.33
C 5	3.09
C 4	2.83
D 7	8.38
D 4	6.97
D 8	6.76
D D 2	6.73
D D 4	6.72
D D 5	5.50
D 1	4.99
D D 3	4.72
D D 6	4.58
D 2	4.44
D 3	4.21
D D 1	4.16
D 5	4.03
D D 7	4.02
D 6	4.01
D D 8	3.62
D 9	3.42
D D 9	2.73

Names and numbers of squares.	Weights of total crops.
C C 9	9.50
C C 8	7.85
C C 2	7.50
C 9	6.85
C C 1	6.25
C C 5, C {3, 6}	5.65
C 2, C C 7	5.25
C {7, 8}	4.75
C C 4	4.35
C C {3, 6}	4.25
C 1	4.15
C 5	3.85
C 4	3.35
D 7	10.75
D 4	9.00
D 8	8.85
D D 4	8.75
D D 2	8.65
D D 5	7.00
D 1	6.35
D D 3	6.25
D D 6	6.00
D 3	5.50
D 6, D D 1, D D 7	5.25
D 2	5.15
D 5	5.00
D D 8	4.75
D 9	4.35
D D 9	3.50

Beans. — 1872.

Names and number of squares.	Weights of beans.
C C 7	2.23
C 4	1.60
C C 8	1.48
C 2	0.90
C C 2	0.65
C C 9	0.53
C {5, 8}	0.34
C {3, 6}	0.29
C 9	0.26
C 1	0.24
C C 5	0.21
C C {1, 3}	0.15
C C 6	0.09
C C 4	0.05
D 4	3.18
D 7	2.29
D D 4	1.78
D 6	0.59
D D 5	0.49
D D 6	0.42
D D 2	0.31
D 8	0.25
D D 3	0.21
D D 9	0.18
D 1	0.16
D 9	0.15
D D 8, D 5	0.14
D 3, D D 7	0.10
D 2	0.06
D D 1	0.03

Names and numbers of squares.	Weights of stalks and husks.
C C 7	2.27
C C 8	1.82
C 4	1.40
C 2	1.10
C C 9	1.07
C C 2	1.00
C 8, C C 6	0.81
C C 5	0.79
C 1	0.76
C C {3, 4}	0.75
C {3, 6}	0.71
C C 1	0.60
C 9	0.59
C 5	0.16
D 4	2.32
D 7	1.71
D D 4	1.57
D 6	1.06
D D 3	0.99
D D 2	0.94
D D 5	0.91
D D 6	0.88
D 5	0.76
D 9	0.70
D D 1	0.62
D {1, 2}	0.59
D D 8	0.56
D 3	0.55
D D 9	0.52
D D 7	0.50
D 8	0.45

Names and numbers of squares.	Weights of total crops.
C C 7	4.50
C C 8	3.30
C 4	3.00
C 2	2.00
C C 2	1.65
C C 9	1.60
C 8	1.15
C C 5, C {1, 3, 6}	1.00
C C {3, 6}	0.90
C 9	0.85
C C 4	0.80
C C 1	0.75
C 7	0.65
C 5	0.50
D 4	5.50
D 7	4.00
D D 4	3.35
D 6	1.65
D D 5	1.40
D D 6	1.30
D D 2	1.25
D D 3	1.20
D 5	0.90
D 9	0.85
D 1	0.75
D 8, D D 8, D D 9	0.70
D {2, 3}, D D 1	0.65
D D 7	0.60

Ruta-Bagas. — 1872.

Names and numbers of squares.	Weights of roots.
C 2	15.00
C C 7	11.25
C C 4	11.00
C 8	9.25
C 3	9.00
C 1	8.00
C C 1	7.50
C 6	7.00
C 7	6.50
C C 2	5.50
C 9	5.25
C 5	5.00
C C 6	4.75
C C 5	3.75
C 4	3.50
C C 8	3.25
C C 9	2.50
C C 3	1.75
D 7	14.50
D 4	10.25
D 8, D D 4	9.75
D D 7	9.25
D 5	7.25
D 2	7.00
D D 2	6.25
D 9	5.75
D D 1	4.75
D {3, 6}	4.50
D 1, D D 5	3.00
D D 8	2.75
D D 9	2.50
D D 6	2.25
D D 3	2.00

Names and numbers of squares.	Weights of tops.
C {6, 7}	17.50
C 2	16.00
C 8	14.50
C 9	14.25
C 1	13.75
C 3, C C {1, 4}	12.50
C C 7	12.25
C 4	11.50
C C 2	9.50
C C 6	8.25
C 5	7.75
C C 8	7.50
C C 9	7.00
C C 3	6.25
C C 5	4.25
D D 2	10.75
D 9	10.25
D 3	9.75
D D 4	9.25
D 6, D D 1	9.00
D 7	8.25
D 2	8.00
D 1	7.50
D 8	7.25
D 5	7.00
D 4	6.75
D D 7	6.50
D D 5	5.25
D D 3	3.25
D D 6	2.50
D D 8	2.25
D D 9	1.50

Names and numbers of squares.	Weights of total crops.
C 2	31.00
C 6	24.50
C 7	24.10
C 8	23.75
C C {4, 7}	23.50
C 1	21.75
C 3	21.50
C C 1	20.00
C 9	19.50
C 4, C C 2	15.00
C C 6	13.00
C 5	12.75
C C 8	10.75
C C 9	9.50
C C {3, 5}	8.00
D 7	22.75
D D 4	19.00
D {4, 8}, D D 2	17.00
D 9	16.00
D D 7	15.75
D 2	15.00
D {3, 5}	14.25
D D 1	13.75
D 6	13.50
D 1	10.50
D D 5	8.25
D D 3	5.25
D D 8	5.00
D D 6	4.75
D D 9	4.00

It is to be observed that although the barley and the bean crops of 1872 are very light, owing in part, no doubt, to the bad season as well as to the exhausted condition of the land, the results obtained with them are, on the whole, excellent. These results are not only perfectly coherent and comparable among themselves, as were those of 1871, but they are actually better than the latter, in so far as the barley crops of 1872 were all safely secured and weighed. No suspicion or uncertainty attaches to any of them, such as the depredations of rats imparted to the crops of 1871.

The results obtained on Sections A and AA are not comparable with those of the remaining sections, since, as has already been stated on page 86, the soil of A and AA is much better than that of the remainder of the experimental field. But it is plain from the other results that the land needs potash rather than phosphoric acid or nitrogen. The addition of potassic manures to the soil manifestly enables the crops to make use of a certain store of phosphoric acid and nitrogen that the land contains. It is clearly shown, moreover, that the amount of available potash in the land must be very small, since neither the phosphatic manures nor the nitrogenous manures by themselves, nor mixtures of the two, such as several of the so-called superphosphates are known to be, could enable the crops to get potash enough from the soil to keep them from starving, after the first year. Enough has been learned evidently from the experiments of 1871–72 to justify the trial next year of mixtures of fertilizers such as shall be competent to supply the place of farm-yard manure upon the field in question.

No. 7. — *A Record of Trials of various Fertilizers upon the Plain-field of the Bussey Institution.* By F. H. Storer. *Third Report. Results obtained in* 1873. *With a Review of the Three Years' Course of Experiments.*

The field experiments of 1873 were of two kinds or classes. Those of the one class were exact repetitions of the experiments of 1871 and 1872, described in the preceding reports; while the other class comprised trials of a number of mixed fertilizers, which were compounded with the view of competing with farm-yard manure. For the sake of convenience, the experiments with mixtures will be described first. The argument on which the mixtures were based was as follows: —

It appears from the best crops obtained in 1871, that as much as 8.5 kilogrammes of barley grain and 23 kilogrammes of barley straw, 10 kilogrammes of beans and 11 kilogrammes of bean straw, 81 kilogrammes of ruta-bagas and 47 kilogrammes of ruta-baga leaves, may be harvested respectively from one of the 5 × 5 metre squares of the experimental field. But from Wolff's table of the average composition of agricultural plants, as shown by analysis (cited in Johnson's "How Crops Grow," New York, 1868, p. 376), we know that there is ordinarily taken off the land in crops of these kinds and amounts the following quantities of potash, phosphoric acid, and nitrogen, namely:—

	By 8.5 kilogrammes of barley grain.	By 23 kilogrammes of barley straw.	Total.	Hence each square should receive about
	Grms.	Grms.	Grms.	Grms.
Potash . . .	41	214	255	250 K_2O.
Phosphoric acid	61	42	103	100 P_2O_5.
Nitrogen . .	128	110	238	200 N.

	By 10 kilogrammes of beans.	By 11 kilogrammes of bean straw.	Total.	Hence each square should receive about
	Grms.	Grms.	Grms.	Grms.
Potash . .	120	209	329	330
Phosphoric acid	80	44	124	125
Nitrogen .	400	176	576	200*

* Only about one third of the amount of nitrogen in the maximum crop was taken, from fear that a large amount might do harm. The experiments of 1871 and 1872 had shown conclusively that in presence of carbonate or sulphate of potash the bean crop could obtain a good deal of nitrogen from the humus in the soil.

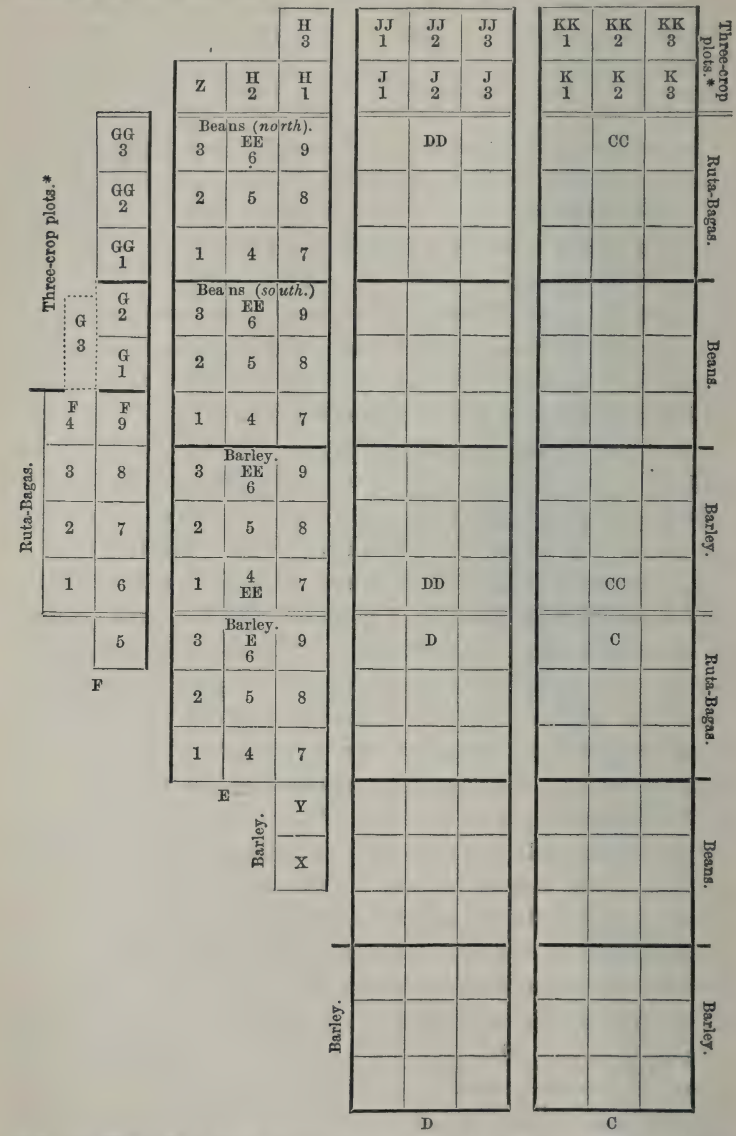
	By 81 kilogrammes of ruta-bagas.	By 47 kilogrammes of ruta-baga leaves.	Total.	Hence each square should receive about
	Grms.	Grms.	Grms.	Grms.
Potash . .	243	150	393	400
Phosphoric acid	81	61	142	150
Nitrogen .	200	about 150	350	200*

The purpose of the mixtures was: 1st, to produce, if possible, crops as large as any that had been previously obtained upon the field by the use of farm-yard manure; 2d, to determine which of the available sources of potash is to be preferred; 3d, to try which of the phosphatic and nitrogenous manures that had been employed in 1871 and 1872 were best suited to use with the potash compounds; and 4th, to get a set of results from mixed fertilizers that could be compared with those already obtained by the use of simple fertilizers and with those that had been obtained with farm and stable manure.

It may here be said that the experiments actually tried with mixed fertilizers were only a part of those originally planned. It was found at the time of planting that the preparation and proper application of such a variety of materials required a very large expenditure of skilled labor, — so much, indeed, that it was altogether impracticable to apply a considerable number of mixtures that had been proposed. The character of some of the fertilizers employed might perhaps have been improved upon. Thus the mixtures of low-grade superphosphate of lime and rough nitrogenized matters that were used in several instances are manifestly ill adapted for the preparation of precise and definite mixtures. But since these materials had been used of necessity for the experiments of 1871 and 1872, at a time when no simple superphosphate could be procured, it was thought best to continue to use them in the manner indicated in the tables: that is to say, an amount of each of the phosphatic manures sufficient to supply the required phosphoric acid was taken in each instance, and a certain allowance was made for the nitrogen that the material contained, as will be seen from the variations in the amounts of sulphate of ammonia and nitrate of soda that were applied to the several squares. The last-named chemicals were, commercially speaking, pure. The mixtures tried and the amounts of crops obtained by their use will appear from the following tables. The arrangement of the squares and their

* Less nitrogen than the theoretical amount was purposely taken.

position as regards Sections D, DD, and CC, described in the previous reports, will be seen from the diagram. Compare page 82.



* In the Three-Crop Plots, square No. 1 carried barley, No. 2 beans, and No. 3 ruta-bagas in every instance. Squares X and Y carried barley, and Z beans. Plot F was entirely devoted to ruta-bagas. The division or unit designated G 3 was a rectangle measuring 8 by 3.13 metres, instead of the usual 5 by 5 metre square.

Section E. — Barley. — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops.		
		Grain.	Straw and chaff.	Total product.
1	Neither crop nor manure			
2	910 grms. sulphate of ammonia . 463 " " " potash . . 714 " Bay State superphosphate	0.765	3.735	4.500
3	895 " sulphate of ammonia . . 463 " " " potash . . . 714 " Coe's superphosphate . .	0.695	3.055	3.750
4	910 " sulphate of ammonia . . 463 " " " potash . . . 833 " Wilson's superphosphate .	0.407	3.593	4.000
5	890 " sulphate of ammonia . . 463 " " " potash . . . 400 " Breck's fine bone-meal .	0.530	3.220	3.750
6	910 " sulphate of ammonia . . 476 " chloride of potassium (83%) 714 " Bay State superphosphate	0.639	2.861	3.500
EE 4	. . . . . No manure	0.392	1.858	2.250
7	910 " sulphate of ammonia . . 368 " pearl-ash . . . . 714 " Bay State superphosphate	0.600	3.150	3.750
8	607 " nitrate of soda . . . . 476 " chloride of potassium (83%) 1530 " fish-scrap	0.472	3.028	3.500
9	1400 " Peruvian guano . . . . 400 " sulphate of potash . . .	1.102	3.898	5.000
Y	13650 " ground oyster-shells . .	0.559	2.191	2.750
X	13650 " oyster-shell lime	0.687	3.063	3.750

Section EE. — Barley. — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops.		
		Grain.	Straw and chaff.	Total product.
1	1164 grms. nitrate of soda . . . . 463 " sulphate of potash . . . 714 " Bay State superphosphate	0.945	4.055	5.000
2	1139 " nitrate of soda . . . . 463 " sulphate of potash . . . 714 " Coe's superphosphate . .	1.381	5.119	6.500
3	1109 " nitrate of soda . . . . 463 " sulphate of potash . . . 450 " Breck's *coarse* bone-meal .	1.516	5.484	7.000
4	. . . . . No manure	0.392	1.858	2.250
5	1133 " nitrate of soda . . . . . 463 " sulphate of potash . . . 400 " fine bone-meal	1.387	4.863	6.250

Section EE. — Barley (continued). — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops. Grain.	Straw and chaff.	Total product.
6	1164 grms. nitrate of soda . . . . 476 " chloride of potassium (83 per cent) . . . . . 714 " Bay State superphosphate	1.195	4.055	5.250
7	1164 " nitrate of soda . . . . 463 " sulphate of potash . . . 833 " Wilson's superphosphate	1.662	5.588	7.250
8	500 " roasted salt-cake . . . 463 " sulphate of potash . . . 714 " Bay State superphosphate	1.271	4.229	5.500
9	. . . . Neither crop nor manure.			

Section EE (South). — Beans. — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops. Beans.	Stalks, leaves, and husks.	Total product.
1	900 grms. sulphate of ammonia . . 611 " " " potash . . . 865 " Bay State superphosphate	4.565	7.316	11.881
2	886 " sulphate of ammonia . . 611 " " " potash . . . 865 " Coe's superphosphate . .	4.449	6.784	11.233
3	860 " sulphate of ammonia . . 611 " " " potash . . . 570 " Breck's coarse bone-meal	4.311	7.288	11.599
G 2	3666 " wood-ashes . . . . . . 660 " pure sulphate of ammonia	5.148	7.153	12.301
4	875 " sulphate of ammonia . . 611 " " " potash . . . 500 " fine bone-meal	4.302	6.634	10.936
5	. . . . . No manure	0.912	2 904	3.816
6	900 " sulphate of ammonia . . 630 " chloride of potassium (83 per cent) . . . . . 865 " Bay State superphosphate	4.219	5.859	10.078
7	. . . . . Neither manure nor seed.			
8	900 " sulphate of ammonia . . 485 " pearl-ash . . . . . . 865 " Bay State superphosphate	5.588	8.280	13.868
9	607 " nitrate of soda . . . . 630 " chloride of potassium (83 per cent) . . . . . 1530 " fish-scrap	5.275	6.786	12.061

Section EE (North). — Beans. — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops.		
		Beans.	Stalks, leaves, and husks.	Total product.
1	1151 grms. nitrate of soda . . . . 611 " sulphate of potash . . 865 " Bay State superphosphate	4.070	6.224	10.294
2	1127 " nitrate of soda . . . . 611 " sulphate of potash . . . 865 " Coe's superphosphate . .	4.829	6.915	11.744
GG 2	3666 " wood-ashes . . . . . 1212 " nitrate of soda	4.856	7.846	12.702
3	1079 " nitrate of soda . . . . 611 " sulphate of potash . . 570 " Breck's coarse bone-meal	4.756	7.167	11.923
Z	13650 " crushed oyster-shells . .	2.107	4.643	6.750
4	1115 " nitrate of soda . . . . 611 " sulphate of potash . . . 500 " fine bone-meal	4.199	6.354	10.553
5	. . . . No manure	1.122	3.086	4.208
6	1151 " nitrate of soda . . . . 630 " chloride of potassium (83 per cent) . . . . . 865 " Bay State superphosphate	3.813	5.912	9.735
H 2	3666 " wood-ashes . . . . . 3100 " fish-scrap	4.974	7.225	12.199
7	1133 " nitrate of soda . . . . 611 " sulphate of potash . . . 1040 " Wilson's superphosphate	5.929	9.100	15.029
8	500 " roasted salt cake . . . 611 " sulphate of potash . . . 865 " Bay State superphosphate	5.005	8.093	13.098
9	1400 " Peruvian guano . . . 550 " sulphate of potash . . .	4.893	8.091	12.984

Plot F. — Ruta-Bagas. — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops.		
		Roots.	Tops.	Total product.
1	1139 grms. nitrate of soda . . . . 740 " sulphate of potash . . . 1070 " Bay State superphosphate	77.00	45.00	122.00
2	1400 " Peruvian guano . . . 680 " sulphate of potash . . .	73.25	55.00	128.25
3	895 " sulphate of ammonia . . 740 " sulphate of potash . . . 1070 " Bay State superphosphate	71.50	44.25	115.75
4	6153 " cotton-seed meal . . . 490 " sulphate of potash . . .	87.00	59.00	146.00

Plot F. — Ruta-Bagas (continued). — 1873.

Nos. of the squares.	Kinds and weights of fertilizers.	Weights of crops.		
		Roots.	Tops.	Total product.
5	600 grms. nitrate of soda; 763 " chloride of potassium (83 per cent); 1530 " fish-scrap; 100 " Bay State superphosphate	67.25	49.50	116.75
6	1146 " nitrate of soda; 763 " chloride of potassium; 1070 " Bay State superphosphate	89.00	54.25	143.25
7	. . . . No manure	55.75	39.75	95.50
8	600 " salt-cake; 740 " sulphate of potash; 1070 " Bay State superphosphate	47.00	27.00	74.00
9	13650 " crushed oyster-shells	12.25	14.00	26.25

Three-Crop Plots. — Barley. — 1873.

Designation of the squares.	Kinds and weights of fertilizers.	Weights of crops.		
		Grain.	Straw and chaff.	Total product.
G	2778 grms. wood-ashes; 660 " sulphate of ammonia	1.540	5.710	7.250
GG	2778 " wood-ashes; 1212 " nitrate of soda	1.305	4.945	6.250
H	4444 " wood-ashes; 3100 " fish-scrap	1.335	5.165	6.500
J	333 " bone-black; 463 " sulphate of potash; 1212 " nitrate of soda	0.382	2.618	3.000
JJ	333 " bone-black; 463 " sulphate of potash; 952 " sulphate of ammonia	0.185	1.815	2.000
K	3100 " fish-scrap; 463 " sulphate of potash	0.452	2.789	3.250
KK	333 " bone-black; 463 " sulphate of potash; 1550 " fish-scrap; 286 " nitrate of soda	0.350	1.900	2.250

Three-Crop Plots. — Beans. — 1873.

Designation of the squares.	Kinds and weights of fertilizers.	Weights of crops. Beans.	Stalks, leaves, and husks.	Total product.
G	3666 grms. wood-ashes 660 " sulphate of ammonia	5.148	7.153	12.301
GG	3666 " wood-ashes 1212 " nitrate of soda	4.856	7.846	12.702
H	3666 " wood-ashes 3100 " fish-scrap	4.974	7.225	12.199
Z	13650 " crushed oyster-shells	2.107	4.643	6.750
J	417 " bone-black 611 " sulphate of potash 1212 " nitrate of soda	3.851	5.101	8.952
JJ	417 " bone-black 611 " sulphate of potash 952 " sulphate of ammonia	3.797	3.832	7.629
K	3100 " fish-scrap 611 " sulphate of potash	3.381	4.769	8.150
KK	417 " bone-black 611 " sulphate of potash 1550 " fish-scrap 286 " nitrate of soda	3.284	4.756	8.040

Three-Crop Plots. — Ruta-Bagas. — 1873.

Designation of the squares.	Kinds and weights of fertilizers.	Weights of crops. Roots.	Tops.	Total product.
G	4444 grms. wood-ashes 660 " sulphate of ammonia	78.00	61.50	139.50
GG	4444 " wood-ashes 1212 " nitrate of soda	89.00	39.00	128.00
H	2778 " wood-ashes 3100 " fish-scrap	66.25	18.75	85.00
J	500 " bone-black 740 " sulphate of potash 1212 " nitrate of soda	65.00	62.00	127.00
JJ	500 " bone-black 740 " sulphate of potash 952 " sulphate of ammonia	54.25	23.50	77.75
K	3100 " fish-scrap 740 " sulphate of potash	114.25	39.50	153.75
KK	500 " bone-black 740 " sulphate of potash 1550 " fish-scrap 286 " nitrate of soda	90.25	28.50	118.75

TABLE SHOWING THE BEST AND THE WORST BARLEY CROPS OBTAINED IN 1873 BY THE USE OF MIXED FERTILIZERS.

Names and nos. of the squares.	Weights of barley grain.	Names and nos. of the squares.	Weights of barley straw.	Names and nos. of the squares.	Weights of total barley crops.
EE 7	1.662	G	5.710	EE 7	7.250
G	1.540	EE 7	5.588	G	
EE 3	1.516	EE 3	5.484	EE 3	7.000
EE 5	1.387	H	5.165	EE 2	6.500
EE 2	1.381	EE 2	5.119	H	
H	1.335	GG	4.945	EE 5	6.250
GG	1.305	EE 5	4.863	GG	
EE 8	1.271	EE 8	4.229	EE 8	5.500
EE 6	1.195	EE 1, 6	4.055	EE 6	5.250
E 9	1.102			EE 1	5.000
EE 1	0.945	E 9	3.898	E 9	
E 2	0.765	E 2	3.735	E 2	4.500
E 3	0.695	E 4	3.593	E 4	4.000
X	0.687	E 5	3.220	E 3	3.750
E 6	0.639	E 7	3.150	E 5	
E 7	0.600	X	3.063	E 7	
Y	0.559	E 3	3.055	X	
E 5	0.530	E 8	3.028	E 6	3.500
E 8	0.472	E 6	2.861	E 8	
K	0.452	K	2.789	K	3.250
E 4	0.407	J	2.618	J	3.000
EE 4	0.392	Y	2.191	Y	2.750
J	0.382	KK	1.900	EE 4	2.250
KK	0.350	EE 4	1.858	KK	
JJ	0.185	JJ	1.815	JJ	2.000

TABLE SHOWING THE BEST AND THE WORST BEAN CROPS OBTAINED IN 1873 BY THE USE OF MIXED FERTILIZERS.

Names and nos. of the squares.	Weights of bean seeds.	Names and nos. of the squares.	Weights of bean straw.	Names and nos. of the squares.	Weights of total bean crops.
* N 7	5.929	N 7	9.100	N 7	15.029
S 8	5.588	S 8	8.280	S 8	13.868
S 9	5.275	N 8	8.093	N 8	13.098
G	5.148	N 9	8.091	N 9	12.984
N 8	5.005	GG	7.846	GG	12.702
H	4.974	S 1	7.316	G	12.301
N 9	4.893	S 3	7.288	H	12.199
GG	4.856	H	7.225	S 9	12.061
N 2	4.829	N 3	7.167	N 3	11.923
N 3	4.756	G	7.153	S 1	11.881
S 1	4.565	N 2	6.915	N 2	11.744
S 2	4.449	S 9	6.787	S 3	11.599

* In this table N stands for EE *north*, and S for EE *south*.

TABLE SHOWING THE BEST AND WORST BEAN CROPS (continued).

Names and nos. of he squares.	Weights of bean seeds.	Names and nos. of the squares.	Weights of bean straw.	Names and nos. of the squares.	Weights of total bean crops.
S 3	4.311	S 2	6.784	S 2	11.233
S 4	4.302	S 4	6.634	S 4	10.936
S 6	4.219	N 4	6.354	N 4	10.553
N 4	4.199	N 1	6.224	N 1	10.294
N 1	4.070	N 6	5.912	S 6	10.078
J	3.851	S 6	5.859	N 6	9.735
N 6	3.813	J	5.101	J	8.952
JJ	3.797	K	4.769	K	8.150
K	3.381	KK	4.756	KK	8.040
KK	3.284	Z	4.643	JJ	7.629
Z	2.107	JJ	3.832	Z	6.750
N 5	1.122	N 5	3.086	N 5	4.208
S 5	0.912	S 5	2.904	S 5	3.816

Owing to the unfavorable season, which will be described further on, the barley crops were all so small that the results tabulated above are hardly worth discussing. It will be noticed, however, that in more than half of the trials with mixed fertilizers the yield of grain was larger than in the case of the best crop obtained by the use of farm manure (see beyond), and that five sixths of these crops were better than the mean of the four trials with farm and stable manure. The ruta-baga crops also, though the season was favorable for the growth of this plant, suffered so much and so irregularly from the depredations of the turnip-fly, that no comparisons can be made between the several squares. Hence no general table of the results obtained with this crop has been given. For example, there were only 30 ruta-baga plants harvested from Square F 8 against 136 plants from K. It can be said only that excellent crops of ruta-bagas were obtained in every instance by the use of the mixed fertilizers. The individual plants were large and fair and sound. With but two exceptions, each of the squares yielded some roots that weighed from three to six kilogrammes apiece. The contrast between these well-fed roots and the miserable specimens obtained from the exhausted soil of Sections C and D was most striking. Many of the latter were smaller than a man's finger. Upon Square D 1, for example, there were 140 plants, but the best root among them weighed 22 grammes. So, too, the best root from Square C 4 weighed 47 grammes.

The bean crops, on the contrary, are good, and remarkable for their uniformity. Thirteen out of the twenty-two squares to which mixed fertilizers were applied yielded at the rate of from 25 to 30 bushels of beans to the acre, while three yielded rather more, and six somewhat less. There was manifestly very little difference in the efficacy of the mixtures. The differences, for example, between the crops on corresponding squares in the north and south plots of Section EE are in general so small that they may fairly be attributed to original differences in the quality of the soil or to the influence of external circumstances. The three best crops of all were doubtless influenced somewhat by the presence of an admixture of farm-yard manure that had been left on the land during the previous years. It has already been stated (on page 84) that the land to which the mixed fertilizers were applied had been left fallow during the years 1871 and 1872, for the express purpose of being devoted to these experiments in due season. The intention was, of course, to have the land left absolutely unmolested, with the exception of an occasional ploughing. But it was found impossible to accomplish this purpose. Thus the teamsters who brought the farm-yard manure, employed in the experiments of 1871 and 1872, would occasionally, in the absence of my assistant or myself, deposit a load of the dung along the edge of Section DD, instead of putting it in the place directed; and although the heaps of manure thus left were immediately removed, some portions of the dung necessarily remained upon the soil. Squares EE 9 in the barley plot, and EE 7 in the south bean plot, had been so clearly vitiated in this way, that nothing was planted upon them. Square EE 8, in the south bean plot, was known to have received a certain amount of contamination, and we were in doubt as to the other squares adjoining Section DD, namely, EE 9, south, and 7, 8, and 9, north; but from curiosity to see what effect, if any, the old manuring might produce, it was decided to plant them all. It is plain that the influence of the old manuring was felt somewhat, and the fact is an important one, which will be discussed further on. It is to be noted meanwhile that the results obtained on the sets of squares numbered 7, 8, and 9 cannot fairly be compared with the rest.

It will be observed that little benefit was derived from the phosphatic and nitrogenous components of the mixed fertilizers. This fact is clearly seen by comparing the results tabulated above with some of

those given beyond, obtained by the use of single fertilizers. Thus Square BB 6, which received in 1873 nothing but 1336 grammes of pearlash, as it had in 1871 and again in 1872, gave a crop of 4.561 kilogrammes of beans; Square B 7, dressed with 307 grammes of sulphate of potash, gave 4.612 kilogrammes of beans; BB 7, dressed with 2267 grammes sulphate of potash, gave 4.322 kilogrammes of beans; and B 4, dressed with 4095 grammes of wood-ashes, gave 4.734 kilogrammes of beans. Not a square in the entire list of those treated with mixtures yielded so large a crop of beans as was obtained from BB 4, which had received nothing but a very heavy dressing of wood-ashes for three successive years; it yielded, namely, in 1873, 6.610 kilogrammes of beans, i. e. 39 bushels to the acre. Wood-ashes gave excellent results when used as a component of the mixtures (see G, GG, and H), as well as in the instances just cited; and there can be little question but that, as a general rule, they would act better as manure than any single potash salt representing as much potash. Wood-ashes are more serviceable than any single potash salt, not only because they contain some phosphoric acid, lime, magnesia, and the other less valuable elements of plant-food, but because, considering them merely as a potassic manure, they contain a mixture of potash salts. It may be regarded as wellnigh certain that a given amount of potash, applied to the land in the form of appropriate mixtures of sulphate, carbonate, silicate, and chloride of potassium, will, generally speaking, do more good than if all the potash were applied in the form of either one of these compounds. But in wood-ashes we find a mixture of these salts ready at hand; not the best mixture perhaps, but one already formed, and in this country, at least, very generally obtainable.

I have little or no doubt but that the proportion of the phosphatic and nitrogenous constituents in the mixed fertilizers employed, and often that of the potash also, might have been lessened very materially in almost every instance without appreciably diminishing the amounts of the bean crops. In other words, it would probably have been better on some accounts if less "complete" mixtures had been employed upon a certain number of the squares of Section EE. The reasons for making the mixtures so complete were, first, the supposed inherent improbability that the supply of nitrogen and phosphoric acid in the land could be sufficient for a maximum crop;

secondly, the fact that somewhat better results had almost always been obtained from wood-ashes in the previous years than from the simple potash-salts; and finally, that not even the heaviest application of wood-ashes had given crops so good as those obtained from several of the squares on Sections A and AA that had been treated with limes. I did not know until the autumn of 1873 how very much richer than the rest of the field the soil of Sections A and AA really was. At the time when the mixtures above mentioned were compounded, I was laboring under the impression that the good results obtained upon Sections A and AA in 1871 and 1872 were to be wholly ascribed to manure that had been applied to the land in 1870. But the continued good results obtained even in 1873, after three years' severe cropping, have convinced me that the land at that end of the field must either have been occupied as a garden in past years or have been on some special occasion drenched and overloaded with fertilizing materials. It need hardly be urged that the conduct of the experiments would have been materially different if the fact of the excessive richness of the land of Sections A and AA could only have been known earlier.

The crops grown upon Squares J, JJ, K, and KK cannot be compared with those from the squares of Sections EE, G, and H; since it was observed that a large part of the soil of each of the squares first mentioned was in very bad condition. Throughout the entire season it could be seen that while the crops grew as well upon parts of each of these squares as they did upon the squares of EE, they languished upon the remaining portions. It was manifest that injury had been done in some way to a strip of land running through the Squares J and JJ, K and KK. I am uncertain whether the trouble may not have been caused by the exposure of subsoil in previous years by dead furrows that perhaps passed through the place now occupied by these squares, or whether the ground had not become compacted by the passage of carts that were employed in 1872 in hauling loam from a neighboring field for the use of the Horticultural Department. Whatever the cause from which the land had suffered, it was found that the injury had not been repaired in a single year by the careful spading to which the land was subjected.

It is to be inferred from the foregoing results, and from those obtained by the use of single fertilizers, that no mere manuring of the land of Section EE could have given a bean-crop much larger than six or seven kilogrammes to the square, or from thirty-six to forty bushels to the acre. It is plain, at all events, that crops so large as these last cannot be obtained economically, since the amount of fertilizing material expended in their production is out of all proportion greater than that which proved sufficient for the growth of crops very nearly as good. It has been seen already that the crops obtained by the use of comparatively small amounts of fertilizers, as in B 4 and B 7, must be vastly better in respect to cost than those from the squares that were heavily manured. Perhaps some happy combination of farm-yard manure and the artificial fertilizers might have increased the crop a little; but the number, thirty-nine bushels to the acre, may fairly be taken as that of the largest crop obtainable by the use of manure upon the land in question *under the conditions that obtained in the year* 1873. So many bushels of beans as this from the acre of poor land is undoubtedly a large yield, and the result is the more striking in view of the almost total failure of the contiguous barley crops; but it would seem to be sufficiently plain that the lavish expenditure of fertilizing materials, by which the largest crops were produced, would be wholly unjustifiable in the actual farming practice of this region.

It has been shown by the German chemist Hellriegel,* that in order to obtain a maximum crop, that is to say, the largest possible crop, of any plant, it is necessary, not only to supply the plant with the various chemical substances which serve as its food, but also to provide certain favorable conditions that are essential to the well-being of the plant, and to present the food under these conditions. Beside mere food the plant must have sufficient standing-room, and plenty of light, heat, air, and moisture. The experiments of Hellriegel show most clearly the enormous influence that is exerted upon the quantity of a crop whenever any one of these conditions is left unfulfilled, or is only partially fulfilled. It is only when each and all of the conditions are favorable, and, as it were, in just proportion, and

* In a most admirable series of researches made at the experimental station at Dahme. See Stœckhardt's *Chemischer Ackersmann*, 1868, **14**, 13; Hoffmann's *Jahresbericht*, 1866, **9**, 146.

when an abundance of each of the necessary fertilizers is at hand, that the "normal crop," that is to say, the best possible crop, is obtained. By attending to all these particulars Hellriegel has succeeded in growing, year after year, upon a tolerably large scale, examples of the several grain crops much larger, healthier, and more perfect in every respect, than have ever been met with in field practice. He has been able, moreover, to produce at will plants of determinate size and weight by varying the conditions aforesaid, though the supply of food was unchanged, and to obtain repeatedly the same results when operating under like conditions.

Applying these truths to the results obtained upon the experimental field of the Bussey Institution, it is plain that this field lacks depth of soil, and, above all, that it lacks water. In respect to these two conditions, the field, like thousands of others in New England, *has a certain natural but limited capacity to profit by the application of manure.* It is useless to apply much manure to such land, unless the season should happen to be specially favorable.

The results of the three years' course of experiments show conclusively that, under the conditions which now obtain, the land is totally unfit for any system of "high farming." On the contrary, in order to be farmed with profit, it must necessarily be given over to some system of low farming, in which the expenditures for labor, tillage, and fertilizers shall be small, and the crops proportionally light. It is plain that the land cannot put to profitable use more than a certain small proportion of fertilizing matters; and for that very reason it can at the best only produce mediocre crops. The land is not "strong" enough naturally to justify the application of large amounts of manure. It cannot give to the manure that support and assistance that is needed, in order that the fertilizing constituents of the manure may be used with advantage, i. e. it cannot supply the conditions necessary for the successful growth of crops. In one word, the land lacks moisture. As has been stated already, on page 80, the surface-soil lies some fifty or sixty feet above the level of the ground-water. The layer of loam in which the plants grow is thin, and the bed of gravel beneath the loam is deep and coarse and open; so that the soil quickly becomes dry after rain, and is therefore, in our climate, constantly exposed to terms of drought. It would be impossible, economically speaking, to deepen such a soil. There is, in fact, but

one sure way to elevate its character, and that is by irrigation, applied to grass or to other crops suited to receive it. In the case of this particular experimental field, it would not be difficult to keep the soil moist by pumping water with a windmill, either from the low valley mentioned on page 80, upon the one side, or from the brook upon the other; and the same thing might be done for a multitude of similar fields throughout the entire country. Mr. Marsh, in his "Man and Nature" (New York, 1864), p. 367, has urged long ago that the natural conditions of Piedmont and Lombardy, where irrigation is bestowed upon almost every crop, are in some respects very like those which obtain in New England. "The summers in Northern Italy, though longer, are very often not warmer than in New England; and in ordinary years the summer rains are as frequent and as abundant in the former country as in the latter. . . . . The necessity of irrigation in the great alluvial plain of Northern Italy is partly explained by the fact that the superficial stratum of fine earth and vegetable mould is very extensively underlaid by beds of pebbles and gravel, brought down by mountain torrents at a remote epoch. The water of the surface-soil drains rapidly down into these loose beds, and passes off by subterranean channels to some unknown point of discharge."

The fact already noticed on page 126, that somewhat heavier crops were obtained from Square EE 8, known to have received some farmyard manure in 1872, and from the other squares, numbered 7, 8, and 9 of that section, which are supposed to have had farm or stable manure thrown upon them in 1871 or 1872, is probably due to the great diffusive or penetrative power of the nitrogenous constituents of dung. Unlike ammonia and potash, the soluble nitrogenized constituents of dung are not immediately "fixed" on coming into contact with the soil. On the contrary, when dissolved in water, they soak into the earth in all directions; and although the diffusion is undoubtedly hindered somewhat by the mechanical attraction of the soil, i. e. by mere adhesion, there is reason to believe that the substances in question are not actually arrested, or even very firmly held, until they have been changed to the condition of ammonia, or to that of some one of the more or less inert nitrogenous constituents of humus. On this view, it is evident that a soil manured with dung, i. e. with dung liquor, must be thoroughly charged in all directions

with nitrogenous matters. Wherever the roots of the crop may turn, they are sure to find an abundance of this particular form of food; just as in land that has been permeated with soluble phosphoric acid by the application of a true superphosphate, the plant can everywhere find all the phosphates it can possibly use. It is easy to explain in this way the high esteem in which dung is justly held. It must usually happen, at least as regards poor soils, that dung will have for this reason a certain superiority as manure over artificial mixtures of chemicals, unless, indeed, means are devised for controlling the fixation and diffusion of the nitrogenized chemicals, such as the ammonium salts and nitrates. Practically, good results could be got, no doubt, by using sulphate of ammonia in the original mixture of fertilizers, and occasionally applying nitrate of soda afterwards. As is well known, the objection to the use of the nitrate by itself, or rather when applied all at once, is its too rapid rate of diffusion. The soil has little power to fix or hold it. Whatever part of it the crop cannot immediately put to use is quickly washed out of the land by rains.

The opinion very generally held by farmers that, even as a mere question of fertilization, without regard to any advantage that may be gained by giving the food to cattle, it is generally speaking better to carry dung from the stable to the field than to plough under a green crop, or, in other words, the common prejudice in favor of manuring with dung, as such, rather than with the vegetable matters from which the dung has been produced, probably depends in good part upon the superior diffusive power of the nitrogenous constituents in the dung. The benefit derived from mere concentration of the fertilizing components, through the removal of the organic matters that are exhaled in the breath of the animals when vegetable substances are reduced to the state of dung, must be largely offset by the costs of transportation and of applying the dung, and a considerable amount of fertilizing material is necessarily lost during the process of concentration.

Trials of Single Fertilizers.

The results of the trials of single fertilizers in 1873 will appear from the tables that are given below. The experiments were absolute repetitions of those of 1871 and 1872, with the exception that a considerable number of the latter were omitted altogether, such, for example, as those of Section DD, and a number of duplicates in C and CC. The reason of these omissions was that the experiments of 1871 and 1872 had shown that no results commensurate with the labor that would have to be expended were to be expected from the further continuance of these particular trials. The land was prepared and planted as in 1872, and the fertilizers were bought and applied in the same way. The season of 1873 was remarkably unfavorable for all early crops, since a drought of almost unprecedented severity prevailed during May and June. In the latter part of July, on the contrary, and through August and September, the season was highly favorable. As a consequence of these conditions the barley crop was completely ruined, the beans did fairly well, and those ruta-baga plants that had escaped the fly grew luxuriantly on all the squares that could supply the necessary food. It should be said of this last crop that the seed employed this year was excellent, but it happened most unfortunately during the dry time that succeeded the moment of sowing (early in June) that the young plants were devastated by the turnip-fly to such an extent and so irregularly that the results obtained have comparatively little value. The harvesting of the beans was conducted with special care this year, with the view of avoiding a certain loss of leaves that occurred in 1872. The leaf-producing power of any given fertilizer is not only a matter of scientific interest in so far as it may serve to indicate the mode of action of the fertilizer; it is a point of no small practical importance in a region devoted to the growth of forage.

The weights of fertilizers used and of crops obtained will appear from the following tables: —

Section A. — Kinds and Weights of Crops, in Kilogrammes. 1873.

Weights of fertilizers, in kilogrammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
13.65 kilos. spent gas-lime	1	0.814	3.186	4.00	5.116	6.024	11.140	100.75	27.75	128.50
13.65 kilos. ground oyster-shells	2	1.062	4.438	5.50	5.384	7.699	13.083	115.75	32.00	147.75
13.65 kilos. oyster-shell lime	3	1.359	5.641	7.00	5.253	7.696	12.949	124.00	34.00	158.00
15.00 kilos. spent-lime from soap-boilers	4	0.785	3.465	4.25	3.902	7.162	11.064	87.25	22.25	109.50
No manure	5	1.022	4.228	5.25	3.574	5.309	8.883	106.50	13.75	120.25
13.65 kilos. Rockland lime	6	1.110	4.390	5.50	3.827	6.013	9.840	90.25	22.75	113.00
0.307 kilos. common salt and 13.65 kilos. oyster-shell lime	7	1.092	3.408	4.50	3.437	5.774	9.211	83.50	22.50	106.00
13.65 kilos. gypsum	8	1.115	4.135	5.25	3.184	4.236	7.420	101.50	24.25	125.75
13.65 kilos. Brandon lime	9	1.320	5.930	7.25	4.837	6.521	11.358	78.75	23.50	102.25

Section AA. — Kinds and Weights of Crops. 1873.

As above, plus 8 cubic feet of Dabney peat. (See page 135.)	1	0.937	3.313	4.250	4.952	7.440	12.392	85.25	21.75	107.00
	2	0.785	2.865	3.750	4.714	6.311	11.025	57.25	11.50	68.75
	3	0.865	4.135	5.000	5.267	7.886	13.153	68.75	26.75	95.50
	4	0.770	2.730	3.500	4.752	6.528	11.280	38.50	3.25	41.75
	5	0.744	2.506	3.250	4.093	6.377	10.470	46.00	16.00	62.00
	6	1.082	4.918	6.000	4.202	5.815	10.017	68.50	13.00	81.50
	7	0.745	2.755	3.500	3.777	6.544	10.321	36.25	15.00	51.25
	8	0.653	2.347	3.000	3.371	6.621	9.992	60.50	22.50	83.00
	9	1.101	4.899	6.000	3.506	5.584	9.090	63.75	21.50	85.25

The peat, or, more properly speaking, mud, put upon Section AA in 1873, came from a pond-hole in Dabney Woods, on Forest Hills Street, Jamaica Plain. The pool in question is at the bottom of a little valley or glen, and is so situated that it receives the wash of several wooded hillsides, besides many leaves of hard-wood trees. The pond was cleared out some six years ago, and the mud thrown up into several large heaps in a moist place. From one of these heaps that had been left undisturbed until now, and upon which sedges and various rank weeds had formed a covering, the material applied to Section AA was taken. A sample of this pond-mud partially air-dried was found to contain

Moisture expelled at 212°	27.97%
Volatile matter, beside moisture	35.01
Ash	37.02
	100.00

The nitrogen in the peat amounted to 0.71 per cent; but no ammonia was expelled on boiling with milk of lime. The ash contained, among other things, —

Phosphoric acid	0.518%
Potash	0.164
Sand insoluble in acid	93.150

An air-dried sample of the peat from Bussey Farm, such as was applied to Section AA in 1871 and 1872, contained

Moisture expelled at 212°	15.24%
Volatile matter beside moisture	77.78
Ash	6.98
	100.00

There was nitrogen to the amount of 1.20 per cent; but no ammonia was obtained on boiling the peat with milk of lime. The ash contained

Phosphoric acid	0.625%
Potash	0.138
Sand insoluble in acid	84.970

There were many shells of diatoms both in the peat and in the pond-mud, though more in the latter than in the former.

In connection with these analyses of peats, a sample of the soil of the Plain-field was examined. It was collected in 1871, before the experiments were begun, from different parts of Section CC. The air-dried soil was found to contain

Moisture expelled at 212°	8.27%
Volatile matter other than moisture	3.64
Ash	88.09
	100.00

The soil contained, among other things, —

Sand, etc., insoluble in acid	82.93%
Lime	0.25
Phosphoric acid	0.25
Potash	0.043
Nitrogen	0.22

It will be seen from the table that the beneficial action of oyster-shell lime and ground oyster-shells is constant and general. Each of the three kinds of crops profited by them, but particularly the beans and the ruta-bagas. Even oyster-shell lime from the gas-works (spent gas-lime) helped the beans and the ruta-bagas, though oyster-shell lime that had been mixed with common salt did not. The quicklimes increased the barley crops as a general rule, manifestly by setting free some assimilable nitrogen compound from the humus in the soil. It is noteworthy in this connection that, even as regards leaves, the oyster-shell lime has usually given better crops than the ground oyster-shells, although the latter contained, of course, a quantity of animal matter proper to the shell which must necessarily be destroyed when the shells are burnt in a kiln. It would be interesting to try what influence upon vegetation would be produced by a mixture of the two. The good effect produced by the oyster-shell products upon the bean crops is manifestly due to the presence of some special fertilizing substance in the shells,* for the other kinds of lime did the beans but little good, excepting only the Brandon lime on A, and the soap-boiler's waste, which is carbonate of lime holding traces of a sodium salt in its pores. The soap-boiler's waste was useless on the barley squares, though it

* Compare various analyses of comminuted sea-shells by Pierre, *Annales chimie t physique*, [3] **37**, 81.

helped the ruta-bagas at times. Unlike the barley, the bean crops did not profit by nitrogen compounds generated in the soil by the action of the limes, except perhaps in a few instances. This fact accords perfectly with what is known of the action of nitrogenous manures upon leguminous crops. The ruta-bagas also, so far as the irregularity of the crops permits the inference, rarely profited from the application of quicklime other than that from oyster-shells. Gypsum occasionally seemed to help the ruta-bagas a little, and sometimes the barley also, but upon the comparatively fertile soil of Sections A and AA it did the beans no good; and the same thing may probably be said of that contained in the superphosphates applied to Sections C and CC.

The results of the experiments on the comparatively fertile land of Sections A and AA clearly strengthen the argument developed on page 129, in discussing the results obtained on Section EE by the use of mixed fertilizers. Under the conditions that obtained in 1873, the land of Sections A and AA was able, of itself, to supply food enough for the support of a considerable bean crop, as it had been in the previous years, and crops of barley and ruta-bagas that were almost as good as those obtained by the use of mixed fertilizers. How little of this effect was produced by the limes may be seen by referring to squares x, y, and z similarly manured on land contiguous to that upon which the mixed fertilizers were applied.

The same line of reasoning is illustrated by a set of experiments made in 1873 at West Peabody, Mass., by Mr. Henry Saltonstall, Treasurer of the Massachusetts Society for Promoting Agriculture, as will be seen from the following table of results which Mr. Saltonstall has been kind enough to send me.

Experiments of Mr. Henry Saltonstall.

The field devoted to these experiments was part of an old worn-out pasture that had not been cultivated in any way for a very long period. It had not been ploughed for fifty years at the least when the sod was turned under in November, 1871. The soil consists of a bed of light loam about six inches deep mixed with stones, resting upon a gravelly subsoil, and not much better situated with regard to its distance from the ground-water than that upon the Plain-field of the

Bussey Institution (see p. 80). The field was left fallow during 1872, and in the spring of 1873 it was cross-ploughed, harrowed, and divided into thirteen strips or plots, each measuring $16\frac{1}{2} \times 104$ feet, and consequently containing about $\frac{1}{23}$ of an acre. Early Rose potatoes were planted in drills upon each of these strips, May 19. There were five drills in each plot. The seed-potatoes were cut so that there was a single eye upon each piece, and care was taken that each of the drills should receive the same number of pieces. With the exception of the manures, the plots were all tilled and treated alike. The kinds and amounts of fertilizers used and the yield of potatoes from each plot are given in the table in terms of pounds.

Nos. of the plots.	Weights of fertilizers used.	Pounds of potatoes harvested.
1	4 lbs. "muriate of potash" of 82 per cent, with hard-coal ashes *	360.5
2	4 lbs. muriate of potash plus 4 lbs. nitrate of soda, with hard-coal ashes *	311
3	No manure	369
4	4 lbs. of the muriate of potash	339
5	4 lbs. of the muriate of potash plus 4 lbs. of nitrate of soda	289
6	4 lbs. of the muriate of potash plus 4 lbs. of nitrate of soda plus 6 lbs. true superphosphate of lime from Mr. Lawes	352.5
7	6 lbs. of the Lawes superphosphate	320
8	6 lbs. of the Lawes superphosphate plus 4 lbs. of the muriate of potash	169
9	4 lbs. nitrate of soda	120
10	11 lbs. nitrate of soda plus 12 lbs. of the Lawes superphosphate †	122
11	4 lbs. nitrate of soda plus 6 lbs. of the Lawes superphosphate	170
12	Stable manure ‡ spread broadcast at the rate of 10 cords per acre	272
13	Stable manure (at same rate as above) plus plaster of paris, both in the drills	365

* The salts were dissolved in water, and the solution was mixed with enough coal-ashes to absorb it completely.

† Formula recommended by Mr. Lawes in a letter addressed by him to the Massachusetts Society for Promoting Agriculture.

‡ The stable manure contained, perhaps, a third of its bulk of peat in both instances.

The heaviest crops were the best in every sense, since they contained the largest and finest potatoes. The small crops were small potatoes. It is noteworthy that the field sloped slightly, in such wise that plots 1 to 5 were a little lower than the rest; though before the potatoes were dug, the lower land had been thought to be poorer than that of the other parts of the experimental field. The slope was insufficient to divert rain-water from the other plots; and, as it happened, very little rain fell during the course of the experiments. For that matter, the drought of 1873 is said to have been rather worse at West Peabody than at the Bussey Farm. It would seem to be plain that in this case also, as well as in the experiments of Sections A and AA, the unmanured strip of land (No. 3) supplied to the potato crop all the food it could make use of under the conditions of this exceptionally dry summer. Since none of the manures applied to the other strips could do more than this, the various mixtures were necessarily useless as regards this particular crop. If the land in question could only have been moistened, the crop of 1873 would have been able to partake not only of the natural supplies of food, and that more readily than was possible under the adverse circumstances that actually obtained, but it would have used the added fertilizers also.

NOTE. — It will be remarked that in several instances, notably in the trials numbered 8, 9, 10, 11, the more soluble saline fertilizers, although applied in very moderate doses, seem to have done distinct harm to the crops. I am inclined to believe that this hurtful influence depends upon the fact noticed by Lawes ("Experimental Investigation into the Amount of Water given off by Plants during their Growth," London, 1850, p. 10), and by Sachs (*Die landwirthschaftlichen Versuchs-Stationen*, 1859, **1**, 203), who find that the absorption of water by the roots of plants and the exhalation of water by their leaves is interfered with and retarded by the presence of saline matters in the soil which surrounds the roots of the plants. It is, of course, readily conceivable that the retardation of the transpiration of water may be beneficial to the plant under certain conditions, as Sachs has urged. But, upon the other hand, it is to be remembered that the free movement of water into and from the plant is a process wellnigh essential to vegetable growth, and that the presence in the soil of matters that tend to check or hinder it may be highly prejudicial to the prosperity of any crop that is not amply supplied with water. In the experiments of Mr. Saltonstall, where the plants were exposed to hot, dry air at a time of severe drought, when the soil could supply only a small fraction of the moisture that was needed for their healthy growth, there is good reason to believe that the saline manures did harm by interfering with the natural movement of water in the plants.

Section B. — Kinds and Weights of Crops, in Kilogrammes. 1873.

Weights of fertilizers, in grammes.	Nos. of the squares.	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
8 cubic feet of cow-manure from a milkman's stable *	1	0.285	2.965	3.250	4.640	7.580	12.020	73.00	21.50	94.50
8 cubic feet of long horse-manure †	2	0.265	1.985	2.250	6.112	9.263	15.375	111.75	30.00	141.75
972 grms. fish-scrap	3	0.070	0.680	0.750	0.433	1.704	2.137	11.50	9.50	21.00
4095 " wood-ashes	4	0.259	1.491	1.750	4.734	7.519	12.253	47.00	13.75	60.75
No manure	5	0.227	1.523	1.750	0.349	3.060	3.409	7.25	5.50	12.75
307 grms. pearl-ash	6	0.575	2.425	3.000	4.021	5.615	9.636	67.50	19.00	86.50
307 " sulphate of potash	7	0.202	1.048	1.250	4.612	3.999	8.611	59.25	17.75	77.00
307 " sulphate of ammonia	8	0.280	1.470	1.750	2.503	7.153	9.656	22.00	11.75	33.75
4095 " New Jersey green-sand	9	0.309	1.441	1.750	2.429	6.683	9.112	35.25	15.00	50.25

Section BB. — Kinds and Weights of Crops. 1873.

Weights of fertilizers, in grammes.	Nos. of the squares.	Grain.	Straw and chaff.	Total product.	Beans.	Stalks, leaves, and husks.	Total product.	Roots.	Tops.	Total product.
8 cubic feet of cow manure from a milkman's stable *	1	0.672	3.578	4.250	4.069	7.472	11.541	131.75	32.75	164.50
8 cubic feet horse-manure †	2	0.461	2.539	3.000	5.636	7.796	13.432	109.00	22.25	131.25
2916 grms. fish-scrap	3	0.270	1.730	2.000	2.636	5.001	7.637	8.25	10.50	18.75
3 bushels wood-ashes	4	0.770	2.980	3.750	6.610	9.976	16.587	137.25	34.25	171.50
No manure	5	0.202	1.048	1.250	0.831	1.967	2.798	13.25	8.25	21.50
1336 grms. pearl-ash	6	0.590	2.410	3.000	4.561	5.928	10.489	52.50	13.75	66.25
2267 " sulphate potash	7	0.496	2.254	2.750	4.322	6.448	10.770	60.00	15.25	75.25
4987 " sulphate ammonia	8	0.162	0.838	1.000	0.862	0.790	1.652	3.75	3.75	7.50
8190 " New Jersey green sand	9	0.402	1.598	2.000	2.685	4.746	7.431	18.50	18.00	36.50

* The cow-manure was fresh and was wellnigh clear dung, being admixed only with a small proportion of refuse hay.
† The stable manure was an average sample. It consisted of dung and *straw*.

As was the case in the previous years, the barley crops of Sections B and BB profited by the application of farm-manure, of wood-ashes, and sulphate of potash. Pearlash seemed to do better this year upon the barley, and the long horse-manure worse than before, as compared with the other fertilizers; though the crops are all so light that the results must be viewed with caution. During the dry weather the barley plants were subjected to conditions so unfavorable to their growth, that even the best manured squares yielded miserable crops. It seems plain, however, that potash was a useful addition to the land, even for the growth of the grain crop, and that beside the potash there was needed for the grain a supply of nitrogen. Comparatively good results were obtained both with the farm manure, rich in nitrogen, and with the sulphate and the carbonate of potash (both that in the wood-ashes and in the pearlash); but both these potash salts do manifestly supply some nitrogen to plants by acting upon that contained in the humus of the soil.

When compared with the results obtained from the other kinds of crops, the experiments with barley illustrate the well-known fact that the grain crops usually profit more by the application of assimilable nitrogen compounds than either the bean crop or the ruta-baga crop. The delicate, short-lived grains seem to have less power than either of the other crops to subsist upon the coarse, nitrogenous food that is obtainable from the soil.

The beans did well with all the potassic manures, namely, the long horse-manure, the wood-ashes, and the carbonate and sulphate of potash. In the absence of potash, nitrogenous manures did the beans no good. So far as the soil of this experimental field is concerned, at least under the present conditions, both sulphate and carbonate of potash have proved to be useful manures. Under the influence of these substances, the bean plants have been able to supply themselves from the soil with both phosphoric acid and nitrogen. The nitrogenous manures, such as sulphate of ammonia and fish-scrap, yielded still less in 1873 than before, now that several successive crops of beans had been taken from the land; and it is noteworthy that the strawy horse-manure gave better results than the cow-manure. The crops obtained by the use of the two kinds of dungs doubtless stand to one another very much in the same pro-

portion as the amounts of potash that are contained in them. It will be noted that the difficultly soluble potash of the New Jersey green sand did little good. Like the experiments made in glass jars, reported on page 65 of this Bulletin, the results of the field experiments enforce the lesson that moisture must be present in order that the green sand shall produce its proper effect.

Upon the ruta-bagas also the action of the potassic fertilizers, even those that contained neither phosphoric acid nor nitrogen, was, comparatively speaking, excellent; but as in the previous years, it is the bean crops that have furnished the most trustworthy and the most interesting results. In accordance with the proverbial ability of this crop to prosper upon poor land, the beans suffered much less than either of the other crops from the hardships to which they were exposed. The results obtained with them are consequently tolerably uniform, and in general easily comprehensible. Several conclusions are, moreover, plainly indicated by the record of these results; but that even the hardy bean crop was most decidedly checked and hampered by the drought, and that it felt severely the limitations imposed by the adverse circumstances to which it was exposed, is clearly shown by the comparatively small differences between the crops harvested from square BB 4, where three bushels, equal to about 65 kilogrammes of wood-ashes, gave 6.610 kilogrammes of beans, and from B 4, where 4.095 kilogrammes of wood-ashes gave 4.734 kilogrammes of beans. In like manner, BB 6, treated with 1.336 kilogrammes of pearlash, gave 4.561 kilogrammes of beans; and B 6, that got only 307 grammes of the pearlash, gave 4.021 kilogrammes of beans. BB 7, to which 2.267 kilogrammes of sulphate of potash were applied, gave only 4.322 kilogrammes of beans, against 4.612 kilogrammes obtained from B 7, that received only 307 grammes of the sulphate. In view of all this, and of the fact that the results just cited are as good or better than those obtained from adjacent squares heavily dressed with farm-manure, it is evident, as has been said already, that something besides the mere fertilizers was needed in order that the beans might really flourish upon the soil of this particular field.

Section C. — Kinds and Weights of Crops, in Kilogrammes. 1873.

Weights of fertilizers, in grammes.	Nos. of the squares.*	Barley.			Beans.			Ruta-Bagas.		
		Grain.	Straw and chaff.	Total product.	Beans.	Stalks and husks.	Total product.	Roots.	Tops.	Total product.
972 grms. of Peruvian guano	2	0.150	0.760	0.910				9.000	8.250	17.250
1365 grms. of Wilson's superphosphate	3	0.023	0.192	0.215	0.238	lost	lost	11.500	11.000	22.500
1638 grms. of crushed bone	4	0.006	0.064	0.070	0.252	1.652	1.904	1.500	2.000	3.500
No manure	5	0.010	0.120	0.130	0.094	1.093	1.187	13.000	9.250	22.250
Section CC. — Kinds and Weights of Crops. 1873.										
1068 grms. of Peruvian guano . . .	2	0.085	0.645	0.730	0.459	2.307	2.766	11.000	11.500	22.500
1485 grms. of Wilson's superphosphate	3	0.052	0.463	0.515	0.165	2.198	2.363	1.250	3.000	4.250
1365 grms. of Breck's flour of bone . .	4	0.155	0.695	0.850	0.030	0.502	0.832	11.000	8.750	19.750
No manure	5	0.045	0.270	0.315	0.137	1.421	1.558	12.750	7.250	20.000
1365 grms. of Bay State superphosphate	7	0.320	1.450	1.770	1.768	4.207	5.975	9.000	10.250	19.250
1450 grms. of Coe's superphosphate .	8	0.091	0.434	0.525	0.984	2.801	3.785	17.000	9.500	26.500
1365 grms. of "XL" superphosphate .	9	0.101	0.599	0.700	0.287	1.622	1.909	7.250	7.750	15.000
Section D. — Kinds and Weights of Crops. 1873.										
144.5 grms. of nitrate of ammonia . .	1	0.007	0.073	0.080	0.282	1.640	1.922	0.250	0.750	1.000
307 grms. of nitrate of soda	2	0.035	0.275	0.310	0.362	1.988	2.350	1.000	0.500	1.500
238.33 grms. of sulphate of ammonia .	3	0.027	0.173	0.200	0.199	3.193	3.392	3.500	6.250	9.750
{ 238.33 grms. of sulphate of ammonia . 314.5 grms. of sulphate of potash . . }	4	0.065	0.595	0.660	3.911	6.077	9.988	5.750	2.250	8.000
No manure	5	0.023	0.177	0.200	0.119	1.138	1.257	3.250	2.750	6.000
193 grms. of chloride of ammonium . .	6	0.075	0.575	0.650	0.350	1.647	1.997	6.750	8.250	15.000
365 grms. of nitrate of potash	7	0.020	0.235	0.255	3.559	5.767	9.326	16.000	6.750	22.750
{ 238.33 grms. of sulphate of ammonia . 581.5 grms. of sulphate of soda . . . }	8	0.125	0.760	0.885	0.178	1.249	1.427	4.500	2.500	7.000
213 grms. of carbonate of ammonia . .	9	0.011	0.104	0.115	0.134	1.281	1.415	7.500	7.750	15.250

* Nothing was planted upon the squares of which no record has been made in the table. The matters lost from square No. 2 (beans) were of small amount.

In 1873, as in the previous years, the phosphatic manures of Sections C and CC proved to be useless for the crops that were grown upon that soil. The experiments have, in fact, shown that the land in question has little or no need of phosphoric acid as clearly as they

have indicated the lack of potash. I am at present unable to say whether the generality of the drift soils of New England are equally well provided for in respect to phosphoric acid. Of course, the remark made above applies in its full force only to the soil of this particular experimental field. As will be shown directly, phosphoric acid seems to be less needed, on the whole, by New England soils, than potash; but there are undoubtedly some soils in the country in which phosphoric acid is lacking, and it is uncertain whether there may not be many soils that contain very much less of it in proportion to the potash than has been found to be the case here.

An interesting illustration of the necessity of restricting the conclusions drawn from field experiments to soils similar to that upon which the experiments were made, and to like conditions, was afforded by the fact that in an old garden at the base of the ridge upon which the Plain-field is situated, and distant some thirty rods from Section C, the yield of beans, peas, and potatoes was decidedly increased in 1872 by the application of one of the mixtures of soluble and insoluble phosphate of lime and fish-scrap, similar to those used in my experiment, which are sold in the Boston market for superphosphate of lime. The soil of this garden is a deep loam that has long been under cultivation, and is very favorably situated with regard to the ground-water.

In the following tables the amounts of each crop obtained by the use of the several fertilizers are given, in the order of excellence, as in the previous reports: —

Tables showing the Best and the Worst Crops obtained in 1873 *from each* Section *of the Field.*

Section **A. — Barley.** — 1873.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
3	1.359	9	5.930	9	7.250
9	1.320	3	5.641	3	7.000
8	1.115	2	4.438	2	5.500
6	1.110	6	4.390	6	
7	1.092	5	4.228	5	5.250
2	1.062	8	4.135	8	
5	1.022	4	3.465	7	4.500
1	0.814	7	3.408	4	4.250
4	0.785	1	3.186	1	4.000

Section **A. — Beans.** — 1873.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	5.384	2	7.699	2	13.083
3	5.253	3	7.696	3	12.949
1	5.116	4	7.162	9	11.358
9	4.837	9	6.521	1	11.140
4	3.902	1	6.024	4	11.064
6	3.827	6	6.013	6	9.840
5	3.574	7	5.774	7	9.211
7	3.437	5	5.309	5	8.883
8	3.184	8	4.236	8	7.420

Section **A. — Ruta-Bagas.** — 1873.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
3	124.00	3	34.00	3	158.00
2	115.75	2	32.00	2	147.75
5	106.50	1	27.75	1	128.50
8	101.50	8	24.25	8	125.75
1	100.75	9	23.50	5	120.25
6	90.25	6	22.75	6	113.00
4	87.25	7	22.50	4	109.50
7	83.50	4	22.25	7	106.00
9	78.75	5	13.75	9	102.25

Section **AA. — Ruta-Bagas.** — 1873.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
1	85.25	3	26.75	1	107.00
3	68.75	8	22.50	3	95.50
6	68.50	1	21.75	9	85.25
9	63.75	9	21.50	8	83.00
8	60.50	5	16.00	6	81.50
2	57.25	7	15.00	2	68.75
5	46.00	6	13.00	5	62.00
4	38.50	2	11.50	7	51.25
7	36.25	4	3.25	4	41.75

Section **AA. — Barley.** — 1873.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
9	1.101	6	4.918	6	6.000
6	1.082	9	4.899	9	
1	0.937	3	4.135	3	5.000
3	0.865	1	3.313	1	4.250
2	0.785	2	2.865	2	3.750
4	0.770	7	2.755	4	3.500
7	0.745	4	2.730	7	
5	0.744	5	2.506	5	3.250
8	0.653	8	2.347	8	3.000

Section **AA. — Beans.** — 1873.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
3	5.267	3	7.886	3	13.153
1	4.952	1	7.440	1	12.392
4	4.752	8	6.621	4	11.280
2	4.714	7	6.544	2	11.025
6	4.202	4	6.528	5	10.470
5	4.093	5	6.377	7	10.321
7	3.777	2	6.311	6	10.017
9	3.506	6	5.815	8	9.992
8	3.371	9	5.584	9	9.090

SECTION **B. — Barley.** — 1873.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
6	0.575	1	2.965	1	3.250
9	0.309	6	2.425	6	3.000
1	0.285	2	1.985	2	2.250
8	0.280	5	1.523	4	1.750
2	0.265	4	1.491	5	
4	0.259	8	1.470	8	
5	0.227	9	1.441	9	
7	0.202	7	1.048	7	1.250
3	0.070	3	0.680	3	0.750

SECTION **B. — Beans.** — 1873.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
2	6.112	2	9.263	2	15.375
4	4.734	1	7 580	4	12.253
1	4.640	4	7.519	1	12.020
7	4.612	8	7.153	8	9.656
6	4.021	9	6.683	6	9.636
8	2.503	6	5.615	9	9.112
9	2.429	7	3.999	7	8.611
3	0.433	5	3.060	5	3.409
5	0.349	3	1.704	3	2.137

SECTION **B. — Ruta-Bagas.** — 1873.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
2	111.75	2	30.00	2	141.75
1	73.00	1	21.50	1	94.50
6	67.50	6	19.00	6	86.50
7	59.25	7	17.75	7	77.00
4	47.00	9	15.00	4	60.75
9	35.25	4	13.75	9	50.25
8	22.00	8	11.75	8	33.75
3	11.50	3	9.50	3	21.00
5	7.25	5	5.50	5	12.75

SECTION **BB. — Ruta-Bagas.** — 1873.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
4	137.25	4	34.25	4	171.50
1	131.75	1	32.75	1	164.50
2	109.00	2	22.25	2	131.25
7	60.00	9	18.00	7	75.25
6	52.50	7	15.25	6	66.25
9	18.50	6	13.75	9	36.50
5	13.25	3	10.50	5	21.50
3	8.25	5	8.25	3	18.75
8	3.75	8	3.75	8	7.50

SECTION **BB. — Barley.** — 1873.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
4	0.770	1	3.578	1	4.250
1	0.672	4	2.980	4	3.750
6	0.590	2	2.539	2	3.000
7	0.496	6	2.410	6	
2	0.461	7	2.254	7	2.750
9	0.402	3	1.730	3	2.000
3	0.270	9	1.598	9	
5	0.202	5	1.048	5	1.250
8	0.162	8	0.838	8	1.000

SECTION **BB. — Beans.** — 1873.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	6.610	4	9.976	4	16.587
2	5.636	2	7.796	2	13.432
6	4.561	1	7.472	1	11.541
7	4.322	7	6.448	7	10.770
1	4.069	6	5.928	6	10.489
9	2 685	3	5.001	3	7.637
3	2.636	9	4.746	9	7.431
8	0.862	5	1.967	5	2.798
5	0.831	8	0.790	8	1.652

SECTION C. — **Barley.** — 1873.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
2	0.150	2	0.760	2	0.910
3	0.023	3	0.192	3	0.215
5	0.010	5	0.120	5	0.130
4	0.006	4	0.064	4	0.070

SECTION C. — **Beans.** — 1873.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
4	0.252	4	1.652	4	1.904
3	0.238	5	1.093	3	?
5	0.094			5	1.187

SECTION C. — **Ruta-Bagas.** — 1873.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
5	13.00	3	11.00	3	22.50
3	11.50	5	9.25	5	22.25
2	9.00	2	8.25	2	17.25
4	1.50	4	2.00	4	3.50

SECTION CC. — **Ruta-Bagas.** — 1873.

Nos. of the squares.	Weights of ruta-baga roots.	Nos. of the squares.	Weights of ruta-baga tops.	Nos. of the squares.	Weights of total ruta-baga crops.
8	17.00	2	11.50	8	26.50
5	12.75	7	10.25	2	22.50
2 } 4 }	11.00	8	9.50	5	20.00
		4	8.75	4	19.75
7	9.00	9	7.75	7	19.25
9	7.25	5	7.25	9	15.00
3	1.25	3	3.00	3	4.25

SECTION CC. — **Barley.** — 1873.

Nos. of the squares.	Weights of barley grain.	Nos. of the squares.	Weights of barley straw.	Nos. of the squares.	Weights of total barley crops.
7	0.320	7	1.450	7	1.770
4	0.155	4	0.695	4	0.850
9	0.101	2	0.645	2	0.730
8	0.091	9	0.599	9	0.700
2	0.085	3	0.463	8	0.525
3	0.052	8	0.434	3	0.515
5	0.045	5	0.270	5	0.315

SECTION CC. — **Beans.** — 1873.

Nos. of the squares.	Weights of bean seeds.	Nos. of the squares.	Weights of bean straw.	Nos. of the squares.	Weights of total bean crops.
7	1 768	7	4.207	7	5.975
8	0.984	8	2.801	8	3.785
2	0.459	2	2.307	2	2.766
9	0.287	3	2.198	3	2.363
3	0.165	9	1.622	9	1.909
5	0.137	5	1.421	5	1.558
4	0.030	4	0.502	4	0.832

SECTION D. — **Barley.** — 1873.

Numbers of the squares.	Weights of barley grain harvested.	Numbers of the squares.	Weights of barley straw and chaff.	Numbers of the squares.	Weights of total barley crops.
8	0.125	8	0.760	8	0.885
6	0.075	4	0.595	4	0.660
4	0.065	6	0.575	6	0.650
2	0.035	2	0.275	2	0.310
3	0.027	7	0.235	7	0.255
5	0.023	5	0.177	3	0.200
7	0.020	3	0.173	5	
9	0.011	9	0.104	9	0.115
1	0.007	1	0.073	1	0.080

SECTION D. — **Beans.** — 1873.

Numbers of the squares.	Weights of bean seeds harvested.	Numbers of the squares.	Weights of bean stalks, leaves, and husks.	Numbers of the squares.	Weights of total bean crops.
4	3.911	4	6.077	4	9.988
7	3.559	7	5.767	7	9.326
2	0 362	3	3.193	3	3.392
6	0.350	2	1.988	2	2.350
1	0.282	6	1.647	6	1.997
3	0.199	1	1.640	1	1.922
8	0.178	9	1.281	8	1.427
9	0.134	8	1.249	9	1.415
5	0.119	5	1.138	5	1.257

SECTION D. — **Ruta-Bagas.** — 1873.

Numbers of the squares.	Weights of ruta-baga roots harvested.	Numbers of the squares.	Weights of ruta-baga tops.	Numbers of the squares.	Weights of total ruta-baga crops.
7	16.00	6	8.25	7	22.75
9	7.50	9	7.75	9	15.25
6	6.75	7	6.75	6	15.00
4	5.75	3	6.25	3	9.75
8	4.50	5	2.75	4	8.00
3	3.50	8	2.50	8	7.00
5	3.25	4	2.25	5	6.00
2	1.00	1	0.75	2	1.50
1	0.25	2	0.50	1	1.00

Tables showing the Best and Worst Crops obtained in 1873 *upon each* **Division** *of the Experimental Field.*

Division A - AA (limes, and limes with peat). **Division B - BB** (chiefly potassic manures).

Barley.—1873.

Names and numbers of squares.	Weights of grain.	Names and numbers of squares.	Weights of straw and chaff.	Names and numbers of squares.	Weights of total crops.
A 3	1.359	A 9	5.930	A 9	7.250
A 9	1.320	A 3	5.641	A 3	7.000
A 8	1.115	A A 6	4.918	A A 6	6.000
A 6	1.110	A A 9	4.899	A A 9	
A A 9	1.101	A 2	4.433	A 2	5.500
A 7	1.092	A 6	4.390	A 6	
A A 6	1.082	A 5	4.228	A 5	5.250
A 2	1.032	A 8	4.135	A 8	
A 5	1.022	A A 3		A A 3	5.000
A A 1	0.937	A 4	3.465	A 7	4.500
A A 3	0.865	A 7	3.408	A 4	4.250
A 1	0.814	A A 1	3.313	A A 1	
A 4	0.785	A 1	3.186	A 1	4.000
A A 2		A A 2	2.865	A A 2	3.750
A A 4	0.770	A A 7	2.755	A A 4	3.500
A A 7	0.745	A A 4	2.730	A A 7	
A A 5	0.744	A A 5	2.506	A A 5	3.250
A A 8	0.653	A A 8	2.347	A A 8	3.000
B B 4	0.770	B B 1	3.578	B B 1	4.250
B B 1	0.672	B B 4	2.980	B B 4	3.750
B B 6	0.590	B 1	2.965	B 1	3.250
B 6	0.575	B B 2	2.539	B 6	
B B 7	0.496	B 6	2.425	B B 2	3.000
B B 2	0.461	B B 6	2.410	B B 6	
B B 9	0.402	B B 7	2.254	B B 7	2.750
B 9	0.309	B 2	1.985	B 2	2.250
B 1	0.285	B B 3	1.739	B B 3	2.000
B 8	0.280	B B 9	1.598	B B 9	
B B 3	0.270	B 5	1.523	B 4	1.750
B 2	0.265	B 4	1.491	B 5	
B 4	0.259	B 8	1.470	B 8	
B 5	0.227	B 9	1.441	B 9	
B 7	0.202	B 7	1.048	B 7	1.250
B B 5		B B 5		B B 5	
B B 8	0.162	B B 8	0.838	B B 8	1.000
B 3	0.070	B 3	0.680	B 3	0.750

Beans.—1873.

Names and numbers of squares.	Weights of beans.	Names and numbers of squares.	Weights of stalks, leaves, and husks.	Names and numbers of squares.	Weights of total crops.
A 2	5.334	A A 3	7.886	A A 3	13.153
A A 3	5.267	A 2	7.699	A 2	13.083
A 3	5.253	A 3	7.696	A 3	12.949
A 1	5.116	A A 1	7.440	A A 1	12.392
A A 1	4.952	A 4	7.162	A 9	11.358
A 9	4.837	A A 8	6.621	A A 4	11.280
A A 4	4.752	A A 7	6.544	A 1	11.140
A A 2	4.714	A A 4	6.528	A 4	11.064
A A 6	4.202	A 9	6.521	A A 2	11.025
A A 5	4.093	A A 5	6.377	A A 5	10.470
A 4	3.902	A A 2	6.311	A A 7	10.321
A 6	3.827	A 1	6.024	A A 6	10.017
A A 7	3.777	A 6	6.013	A A 8	9.992
A 5	3.574	A A 6	5.815	A 6	9.840
A A 9	3.506	A 7	5.774	A 7	9.211
A 7	3.437	A A 9	5.584	A A 9	9.090
A A 8	3.371	A 5	5.309	A 5	8.883
A 8	3.184	A 8	4.236	A 8	7.420
B B 4	6.610	B B 4	9.976	B B 4	16.587
B 2	6.112	B 2	9.263	B 2	15.375
B B 2	5.636	B B 2	7.796	B B 2	13.432
B 4	4.734	B 1	7.580	B 4	12.253
B 1	4.640	B 4	7.519	B 1	12.020
B 7	4.612	B B 1	7.472	B B 1	11.541
B B 6	4.561	B 8	7.153	B B 7	10.770
B B 7	4.322	B 9	6.683	B B 6	10.489
B B 1	4.069	B B 7	6.448	B 8	9.656
B 6	4.021	B B 6	5.928	B 6	9.636
B B 9	2.685	B 6	5.615	B 9	9.112
B B 3	2.636	B B 3	5.001	B 7	8.611
B 8	2.503	B B 9	4.746	B B 3	7.637
B 9	2.429	B 7	3.999	B B 9	7.431
B B 8	0.862	B 5	3.060	B 5	3.409
B B 5	0.831	B B 5	1.967	B B 5	2.798
B 3	0.433	B 3	1.704	B 3	2.137
B 5	0.349	B B 8	0.790	B B 8	1.652

Ruta-Bagas.—1873.

Names and numbers of squares.	Weights of roots.	Names and numbers of squares.	Weights of tops.	Names and numbers of squares.	Weights of total crops.
A 3	124.00	A 3	34.00	A 3	158.00
A 2	115.75	A 2	32.00	A 2	147.75
A 5	106.50	A 1	27.75	A 1	128.50
A 8	101.50	A A 3	26.75	A 8	125.75
A 1	100.75	A 8	24.25	A 5	120.25
A 6	90.25	A 9	23.50	A 6	113.00
A 4	87.25	A 6	22.75	A 4	109.50
A A 1	85.25	A 7	22.50	A A 1	107.00
A 7	83.50	A A 8		A 7	103.00
A 9	78.75	A 4	22.25	A 9	102.25
A A 3	68.75	A A 1	21.75	A A 3	95.50
A A 6	68.50	A A 9	21.50	A A 9	85.25
A A 9	63.75	A A 5	16.00	A A 8	83.00
A A 8	60.50	A A 7	15.00	A A 6	81.50
A A 2	57.25	A 5	13.75	A A 2	68.75
A A 5	46.00	A A 6	13.00	A A 5	62.00
A A 4	38.50	A A 2	11.50	A A 7	51.25
A A 7	35.25	A A 4	3.25	A A 4	41.75
B B 4	137.25	B B 4	34.25	B B 4	171.50
B B 1	131.75	B B 1	32.75	B B 1	164.50
B 2	111.75	B 2	30.00	B 2	141.75
B B 2	109.00	B B 2	22.25	B B 2	131.25
B 1	73.00	B 1	21.50	B 1	94.50
B 6	67.50	B 6	19.00	B 6	86.50
B B 7	60.00	B B 9	18.00	B 7	77.00
B 7	59.25	B 7	17.75	B B 7	75.25
B B 6	52.50	B B 7	15.25	B B 6	66.25
B 4	47.00	B 9	15.00	B 4	60.75
B 9	35.25	B 4	13.75	B 9	50.25
B 8	22.00	B B 6		B B 9	36.50
B B 9	18.50	B 8	11.75	B 8	33.75
B B 5	13.25	B B 3	10.50	B B 5	21.50
B 3	11.50	B 3	9.50	B 3	21.00
B 5	7.25	B B 5	8.25	B B 3	18.75
B B 3	8.25	B 5	5.50	B 5	12.75
B B 8	3.75	B B 8	3.75	B B 8	7.50

Tables showing the Best and Worst Crops (continued).

Division C-CC (phosphatic manures).

Barley.—1873.

Names and numbers of squares.	Weights of grain.	Names and numbers of squares.	Weights of straw and chaff.	Names and numbers of squares.	Weights of total crops.
C C 7	0.320	C C 7	1.450	C C 7	1.770
C C 4	0.155	C 2	0.760	C 2	0.910
C 2	0.150	C C 4	0.695	C C 4	0.850
C C 9	0.101	C C 2	0.645	C C 2	0.730
C C 8	0.091	C C 9	0.599	C C 9	0.700
C C 2	0.085	C C 3	0.463	C C 8	0.525
C C 3	0.052	C C 8	0.434	C C 3	0.515
C C 5	0.045	C C 5	0.270	C C 5	0.315
C 3	0.023	C 3	0.192	C 3	0.215
C 5	0.010	C 5	0.120	C 5	0.130
C 4	0.006	C 4	0.064	C 4	0.070

Beans.—1873.

Names and numbers of squares.	Weights of beans.	Names and numbers of squares.	Weights of stalks, leaves, and husks.	Names and numbers of squares.	Weights of total crops.
C C 7	1.768	C C 7	4.207	C C 7	5.975
C C 8	0 984	C C 8	2.801	C C 8	8.785
C C 2	0.459	C C 2	2.307	C C 2	2.766
C C 9	0.287	C C 3	2.198	C C 3	2.363
C 4	0.252	C 4	1.652	C C 9	1.909
C 3	0.238	C C 9	1.622	C 4	1.904
C C 3	0.165	C C 5	1.421	C C 5	1.558
C C 5	0.137	C 5	1.093	C 5	1.187
C 5	0.094	C C 4	0.502	C C 4	0.832
C C 4	0.030				

Ruta-Bagas.—1873.

Names and numbers of squares.	Weights of roots.	Names and numbers of squares.	Weights of tops.	Names and numbers of squares.	Weights of total crops.
C C 8	17 00	C C 2	11.50	C C 8	26.50
C 5	13.00	C 3	11.00	C 3 } C C 2 }	22.50
C C 5	12.75	C C 7	10.25		
C 3	11.50	C C 8	9.50	C 5	22.25
C C 2 } C C 4 }	11.00	C 5	9.25	C C 5	20.00
		C C 4	8.75	C C 4	19.75
C 2 } C C 7 }	9.00	C 2	8.25	C C 7	19.25
		C C 9	7.75	C 2	17.25
C C 9	7.25	C C 5	7.25	C C 9	15.00
C 4	1.50	C C 3	3.00	C C 3	4.25
C C 3	1.25	C 4	2.00	C 4	3.50

In the following tables the results obtained with the single fertilizers during each of the three years 1871, 1872, and 1873 are given in such form that the action of any one fertilizer of a given class or division may be seen at a glance. Taking Sections A and AA, for example, together, the comparative merits of the several fertilizers employed upon the eighteen squares devoted to each of the three kinds of crops are stated in the table in terms of *eighteenths;* the best crop of all being called No. 1, and the worst No. 18. Whenever the crops from two or more of the squares happened to weigh the same amount, one and the same number, of course, applies to each of them. In that event, the next-best crops have received higher numbers than they in strict justice deserved, and the worst crop of all has been called, not No. 18, but 17, 16, or, it may be, a still lower number. So, too, in the case of the duplicate trials of farm and stable manure on Sections B and BB, only the best of the two results actually obtained has been taken into consideration here. On account of the irregularities thus introduced, several of the comparisons are a little less satisfactory than they would otherwise have been. The worst crop is marked with an asterisk in every instance.

TABLE OF THE COMPARATIVE MERIT OF THE FERTILIZERS USED UPON **Sections A** AND **AA,** STATED IN TERMS OF EIGHTEENTHS.

Kinds of fertilizers used.	GRAIN OR FRUIT.									LEAVES, STALKS, OR TOPS.									TOTAL CROP.								
	Barley.			Beans.			Ruta-Bagas.			Barley.			Beans.			Ruta-Bagas.			Barley.			Beans.			Ruta-Bagas.		
	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873
Oyster-shell lime	2	2	1	3	2	3	2	9	1	2	1	2	2	1	3	9	5	1	2	1	2	2	2	3	3	9	1
Oyster-shell lime with peat	11	3	11	5	5	2	1	10	11	3	9	8	3	6	1	1	13	4	6	4	6	4	6	1	1	15	11
Rockland lime	4	11	4	15	14	12	8	5	6	4	4	6	15	8	13	*18	2	7	3	4	4	16	11	14	13	3	6
Rockland lime with peat .	13	7	7	16	11	9	12	*15	12	5	5	3	6	12	14	11	4	15	8	3	3	14	12	12	11	11	14
Brandon lime	1	13	2	*18	16	6	15	7	10	10	16	1	17	14	9	5	3	6	4	12	1	17	16	5	10	5	10
Brandon lime with peat. .	5	6	5	14	15	15	10	6	13	7	3	4	10	16	16	2	7	11	6	2	3	15	15	16	4	7	12
Soap-boiler's lime . . .	9	10	13	6	6	11	16	12	7	12	10	9	12	7	5	17	14	9	9	7	8	7	7	8	*17	16	7
Soap-boiler's lime with peat	17	16	14	8	7	7	14	14	17	15	*18	15	4	11	8	16	15	*17	15	*14	11	6	8	6	16	*17	*18
Lime and salt	10	4	6	12	13	16	11	4	9	16	15	10	16	15	15	3	8	8	13	9	7	12	14	15	8	6	9
Lime and salt with peat .	16	9	15	7	10	13	17	1	*18	17	12	14	13	10	7	6	4	13	*16	10	11	9	10	11	12	2	17
Gypsum	3	5	3	17	*18	*18	9	7	4	9	8	8	*18	*18	*18	4	7	5	5	5	5	*18	*18	*18	9	8	4
Gypsum with peat . . .	12	14	*17	13	12	17	*18	8	14	14	11	*17	7	13	6	10	11	8	12	10	*13	13	13	13	14	10	13
Oyster-shell flour	6	15	8	1	1	1	4	2	2	1	14	5	1	2	2	12	1	2	1	11	4	1	1	2	5	1	2
Oyster-shell flour with peat	14	7	13	4	4	8	3	10	15	11	13	13	8	5	11	7	12	16	11	8	10	5	4	9	2	14	15
Gas-lime	15	8	12	2	3	4	5	3	5	6	7	12	5	3	12	14	6	3	10	6	9	3	3	7	6	4	3
Gas-lime with peat . . .	7	1	10	10	8	5	6	11	8	*18	6	11	9	4	4	8	9	10	15	2	8	8	5	4	4	12	8
No manure	8	12	9	11	17	14	7	11	3	8	2	7	14	17	17	13	10	14	7	3	5	11	17	17	7	13	5
Nothing but peat	*18	*17	16	9	9	10	13	13	16	13	17	16	11	9	10	15	*16	12	14	13	12	10	9	10	15	16	16

TABLE OF THE COMPARATIVE MERIT OF THE FERTILIZERS USED UPON **Sections B** AND **BB,** STATED IN TERMS OF EIGHTEENTHS.

Kinds of fertilizers used.	Grain or Fruit.									Leaves, Stalks, or Tops.									Total Crop.§								
	Barley.			Beans.			Ruta-Bagas.			Barley.			Beans.			Ruta-Bagas.			Barley.			Beans.			Ruta-Bagas.		
	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873
The best of the two squares dressed with farm-manure	1	2	2	3	1	4	1	2	2	1	2	1	1	1	4	1	3	2	1	2	1	2	1	4	1	2	2
The best of the two squares dressed with stable manure	4	4	6	1	4	2	2	1	3	2	5	3	2	7	2	2	1	3	3	4	4	1	6	2	2	1	3
Wood-ashes, heavy . . .	2	1	1	2	2	1	3	5	1	3	1	2	4	2	1	3	7	1	2	1	2	3	2	1	3	7	1
Wood-ashes, light . . .	10	13	11	8	5	3	9	8	8	9	13	10	7	4	4	10	8	9	10	11	6	8	4	3	10	8	8
Pearl-ash, heavy	8	5	3	5	6	6	5	8	7	10	11	5	5	5	8	5	11	9	9	8	3	6	5	6	5	11	7
Pearl-ash, light	9	7	4	9	10	8	7	3	4	8	6	4	9	11	9	12	4	4	8	6	3	9	10	8	11	3	4
Sulphate of potash, heavy .	3	3	5	4	3	7	4	*15	5	4	3	6	4	3	7	4	*14	7	4	3	4	5	3	5	4	*16	6
Sulphate of potash, light .	13	11	13	11	7	5	8	6	6	12	*16	13	8	9	12	8	6	6	12	*14	7	10	8	10	8	6	5
Sulphate of ammonia, heavy	5	12	14	10	13	13	10	14	*16	6	10	14	10	15	*16	7	11	*15	6	9	8	11	13	*16	7	14	*16
Sulphate of ammonia, light	7	*15	9	6	8	11	6	4	10	7	7	11	6	8	5	9	5	10	7	8	6	7	9	7	6	5	11
Fish-scrap, heavy	6	6	10	7	9	10	11	14	15	5	4	7	3	6	10	6	13	11	5	5	5	4	7	11	9	15	14
Fish-scrap, light	*14	13	*15	13	15	15	12	7	13	13	15	*15	*13	15	15	13	2	12	13	13	*9	13	15	15	13	4	13
New Jersey green-sand, heavy	-	9	7	--	12	9	--	10	11	--	8	8	--	12	11	--	10	5	.	7	5	--	12	12	--	10	10
New Jersey green-sand, light	-	8	8	--	11	12	--	9	9	--	9	12	--	10	6	--	8	8	--	7	6	--	11	9	--	9	9
No manure on Section B .	12	14	12	*14	*16	*16	*14	12	14	*14	14	9	12	*16	13	*14	9	14	*14	12	6	*14	*16	13	*14	14	15
No manure on Section BB .	11	10	13	12	14	14	13	13	12	11	12	13	11	13	14	11	13	13	11	10	7	12	14	14	12	15	12

TABLE OF THE COMPARATIVE MERIT OF THE FERTILIZERS USED UPON **Sections C** AND **CC,** STATED IN TERMS OF EIGHTEENTHS.

Kinds of fertilizers used.	Grain or Fruit.						Leaves or Tops.						Total Crop.					
	Barley.		Beans.		Ruta-Bagas.		Barley.		Beans.		Ruta-Bagas.		Barley.		Beans.		Ruta-Bagas.	
	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872
Bay State superphosphate, best of two	8	8	1	1	7	2	5	10	2	1	7	1	4	7	1	1	5	3
Bay State superphosphate, worst of two	12	12	4	?	8	9	17	11	4	?	12	7	11	8	4	13	7	5
Coe's superphosphate, heavy	2	2	3	3	10	16	3	2	1	2	5	12	2	2	2	2	9	13
Coe's superphosphate, light	13	11	7	7	11	4	*18	12	12	7	4	3	*12	8	8	7	8	4
"XL" superphosphate, best of two	4	1	8	6	9	11	1	1	5	5	1	4	1	1	6	6	10	9
"XL" superphosphate, worst of two	6	3	12	9	16	17	11	4	14	13	9	13	7	4	12	10	12	14
Wilson's superphosphate, heavy	7	14	11	12	*17	*18	10	13	15	10	10	14	6	10	11	9	13	*15
Wilson's superphosphate, light	15	5	13	8	1	5	8	8	7	11	6	6	8	6	10	8	1	7
Breck's crushed bone	16	*16	2	2	11	15	13	*18	3	3	8	8	10	*13	3	3	11	10
Breck's flour of bone	9	11	14	*14	6	3	4	14	8	10	11	6	3	9	12	11	6	5
Bradley's bone-meal, heavy	10	4	16	12	4	7	12	5	10	12	3	6	9	5	13	12	2	8
Bradley's bone-meal, light	*18	15	6	10	12	6	15	15	13	9	*16	5	*12	11	7	8	16	6
Floated bone, heavy	3	9	*18	13	13	13	14	16	16	7	14	10	5	10	*16	9	14	11
Floated bone, light	11	6	15	8	14	8	9	7	*17	11	14	1	9	6	15	8	15	2
Peruvian guano, heavy	5	2	5	5	5	10	2	3	6	6	2	9	2	3	5	5	3	10
Peruvian guano, light	17	10	10	4	2	1	7	9	9	4	14	2	7	7	9	4	5	1
No manure (on Section C)	14	13	9	7	16	12	16	17	7	*14	15	11	*12	12	8	*14	*17	12
No manure (on Section CC)	1	7	17	11	3	14	6	6	11	8	13	*15	3	6	14	8	4	*15

TABLE OF THE COMPARATIVE MERIT OF THE FERTILIZERS USED UPON **Sections D** AND **DD,** STATED IN TERMS OF EIGHTEENTHS.

Kinds of fertilizers used.	Grain or Fruit.						Leaves or Tops.						Total Crop.					
	Barley.		Beans.		Ruta-Bagas.		Barley.		Beans.		Ruta-Bagas.		Barley.		Beans.		Ruta-Bagas.	
	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872	1871	1872
Nitrate of potash, heavier	4	1	3	2	6	1	8	1	3	2	14	6	6	1	3	2	12	1
Nitrate of potash, lighter	1	3	1	3	1	3	1	5	1	3	4	4	1	4	1	3	1	2
Nitrate of soda, best of the two	12	13	15	15	7	6	11	10	7	11	1	5	12	11	10	13	2	6
Nitrate of soda, worst of the two	14	*17	16	*16	9	9	12	12	12	12	12	7	12	12	13	13	10	8
Sulphate of ammonia	16	9	17	14	13	10	4	11	10	14	9	3	10	10	11	13	13	7
Sulphate of ammonia and sulphate of potash	8	3	2	1	8	2	6	2	2	1	16	11	5	2	2	1	16	3
Sulphate of ammonia and sulphate of soda	6	2	12	8	12	3	5	3	13	*17	*18	9	4	3	13	12	*18	3
Chloride of ammonium	17	10	5	4	3	10	16	15	9	4	13	5	15	11	6	4	8	9
Nitrate of ammonia	*18	8	11	11	*15	11	*18	7	8	12	10	8	*17	7	8	11	17	10
Carbonate of ammonia	11	15	10	12	8	8	15	17	17	10	15	2	14	15	14	10	14	4
Cotton-seed meal	13	11	*18	14	4	4	13	14	*18	16	7	12	13	11	*16	*14	5	5
Flocks (powdered woollen rags)	7	12	7	13	5	12	9	16	14	13	6	16	8	14	11	12	6	13
Leather parings	5	16	9	10	14	13	14	*18	15	15	11	*17	11	*16	12	12	15	*15
Common salt	2	7	8	6	11	14	2	9	11	8	8	15	2	9	9	6	11	14
Sulphate of soda (roasted salt-cake)	3	4	6	7	6	7	3	4	4	6	2	1	3	5	5	7	3	3
Silicate of soda	9	5	14	9	10	*15	7	8	6	5	3	14	7	8	7	8	4	12
No manure (on Section D)	15	14	13	13	2	5	17	13	16	9	17	10	16	13	15	9	9	7
No manure (on Section DD)	10	6	4	5	7	11	10	6	5	7	5	13	9	6	4	5	7	11

It will be remembered that the original motive (page 81) of the experiments was to determine, if possible, what kinds of fertilizers among those readily procurable in Boston were best fitted to increase the yield of crops grown upon a field that had been chosen as the typical representative of the light and hungry soils resting upon drift gravel that are so common in New England. This question has been clearly answered by the results that have been tabulated in the present report and in the reports of the two previous years. It is plain that the soil of the experimental field needs fertilizers that are rich in potash, and that, under the existing condition of things, no advantage can be gained by applying mere phosphatic or nitrogenous fertilizers to the land. The soil evidently contains a much larger store of phosphatic and nitrogenous substances that are available for the use of plants than it does of potash compounds. Hence very little useful effect has been gained by adding phosphates and nitrogen compounds to the potassic manures. If only potash enough be given to this soil, the latter can of itself supply all the other ingredients that compose the food of plants, at least for the term of years during which the experiments have lasted, and for as many more, of course, as the store of phosphates and nitrogen may hold out. Consequently until such time as the natural supply of these substances shall begin to fail, it would be wise to apply but little of them. The crying want of the land is for potash, and it is the potassic manures that should be applied to it, to the wellnigh complete exclusion of other fertilizers, until an equilibrium has been reached.

This conclusion is most directly and clearly enforced by the experiments above recorded, in so far as regards the soil of the experimental field; and from analogy it would naturally be inferred that the same conclusion would apply to other New England soils similarly composed and situated. But in order to establish this general conclusion beyond all chance of doubt, it would be necessary to make many other experiments in different localities, were there not already a mass of confirmatory evidence bearing upon the subject. There are, in fact, already available a number of observations, usages, and traditions that go far to prove that the potassic manures are specially needed in New England. It has long been believed, for example, — for a century probably, and perhaps for a still longer period, — by the

farmers near Boston, that night-soil is a "forcing" manure that soon "exhausts the land" to which it is applied. The long horse-manure, on the contrary, from the stables of that city, which is a mixture of dung with much straw that has served for bedding the animals, has always been held in high esteem by the farmers of the locality, in spite of the fact that the dung almost always undergoes fermentation before it is removed from the cellars of the stables, and must, consequently, have lost much of the nitrogen that was originally contained in it. For this ill-kept horse-manure the farmers are glad to pay the stable-keepers a considerable price in the first instance, and they are afterwards at the expense of transporting the bulky material some miles into the country, and are often put to the further cost of rehandling it at the farm. But for night-soil there is no quick market. By far the larger part of that produced in the city finds its way to the sea. Even in the times when water-closets were unknown, and the present system of discharging the filth of the city into its sewers had no existence, thousands of tons of night-soil were shot overboard from the city wharves and bridges, in order to avoid the expense of hauling it four or five miles to the farm land.

But horse-manure is a potassic manure, while night-soil, whether fresh or stale, is not. The hay and oats eaten by the horses of an American city and the straw upon which the horses sleep all contain a much larger proportion of potash than do the bread and meat and vegetables that serve as human food. The more thoroughly, moreover, the original horse-manure has been wasted by fermentation, so much the richer in potash will be the matters that are left. But night-soil when fresh is rich in nitrogen, and when old it is a phosphatic manure charged with more or less nitrogen; the proportion of potash contained in it at any time is, comparatively speaking, small. Hence upon soils that lack potash, night-soil can produce only a temporary useful effect. The active nitrogen contained in it would naturally "force" the soil to give up to the first crops what little available potash it might possess, and the land would thus be "exhausted."*

It is a noteworthy fact that some of the farmers in the vicinity of Boston who habitually make use of night-soil are accustomed to mix with it the strawy horse-manure just mentioned, obtained from stables

* Compare the results obtained by the use of sulphate of ammonia and by that of fish-scrap on Sections B and BB, squares 3 and 8, during the three years.

in the city; for the reason, as they say, that the liquid portion of the night-soil may be absorbed by the straw, and the offensive smell diminished. But it is plain that by this method of procedure they really prepare a *complete manure,* which from some points of view might be regarded as an almost perfect mixture of fertilizers. It is no wonder that these skilful persons should have reason to believe, as they do, in the peculiar efficacy of night-soil, or that they should marvel at their brother farmers' persistence in a prejudice against it which to them seems highly absurd. Equally good results could probably be obtained by using night-soil in conjunction with potash salts from Stassfurt, or with wood-ashes brought by rail from the interior. So long as the cesspool system of disposing of night-soil continues to find place in our cities or in their suburbs, this substance will be one cheap resource for the neighboring farmers. There may, I think, have been a time in the history of the country around Boston when one at least of the best systems of farming possible under the circumstances of the locality, might have been based upon the combined use of horse-manure and night-soil brought from the city; though probably it would usually have been best to use some wood-ashes also. It would be an interesting question, to be determined in actual farm practice, how much the system of farming just indicated could be improved upon to-day in the environs of Boston, in so far as the economical use of fertilizers is concerned.* A very good appreciation of the matter was shown long ago by a successful farmer of West Cambridge, Mr. George Pierce. In 1841 he assured Mr. Colman, at that time State Commissioner for the Agricultural Survey of Massachusetts, that he valued very highly stable manure, brought from Boston, and night-soil that had been composted, and that he had a high estimation for wood-ashes. "When the soap-boiler calls to buy *his* ashes for the customary price of ten cents a bushel, he replies by offering the soap-boiler twenty cents a bushel for all *he* has,

* As regards the continued use of night-soil by itself, the following passage from Oliphant's Narrative of Elgin's Mission to China, Vol. I. p. 252, is of interest. Near Shanghai the author saw "fields of wheat, beans, etc., reeking with high-flavored manure, but bearing, nevertheless, thin crops and abundance of weeds. The land in China, even in the elaborate cultivation of their kitchen-gardens, is never properly worked. The surface merely is scratched and then deluged with strong manure. The consequence is, that though the young crops sometimes look green and promising, they seldom bear heavily."

and buys them if he can. I give his opinions as those of a strictly practical man, of much experience, and perhaps inferior to none in the admirable skill and success of his cultivation."*

The fact that Peruvian guano never gained that popularity in New England which was very generally accorded to it in more fertile regions is another item of evidence of similar import to that just adduced with regard to night-soil. Many of the unsatisfactory results obtained by the use of guano in field practice hereabouts must, no doubt, be ascribed to lack of moisture or to erroneous methods of application, such as frequently occasioned disappointment in all countries in the days when guano first came into use. But it would seem to be plain that the bad repute in which this powerful manure is still held by many a New-Englander must depend upon some cause more general than either of the foregoing. In a word, the facts that guano is but little esteemed by the farmers of this region, and that they deem it an exhaustive manure, go to show that our soils lack potash. The experience of our farmers with guano, as with night-soil, has proved very conclusively that in general no long-continued succession of good crops can be obtained from our soil by the use of manures which do not contain an adequate supply of potash.

It has often been urged directly that potassic fertilizers must be specially needed by New England soils, since the application of wood-ashes is almost everywhere attended with good effects. Throughout the old grazing districts of New Hampshire, for example, the inhabitants firmly believe that the land has "run out," because too much *potash* has been taken from it by continually carrying off hay for the winter's support of cattle. But their argument lacks precision, based as it is upon the theoretical inference just stated, and upon the experimental fact, well known in that region, as it is almost everywhere in New England, that wood-ashes have a remarkable effect in recuperating worn-out lands; for both the exhaustion by cropping and the fertilizing action of the ashes might be due to phosphates taken off in the hay and contained in the ashes as much as to potash or even more. In consequence of this uncertainty, chemists and agricultural writers have often paid less attention to the popular convic-

* H. Colman, Fourth Report of the Agriculture of Massachusetts, Boston, 1841, p. 406.

tion than it really deserved. As has been seen already, the justice of it is strongly corroborated both by the experiments, the experience, and the practices above described.

The question naturally suggests itself, What is the reason of this dearth of potash? Why is it that a fertilizer which has, comparatively speaking, little repute in Europe, should be deemed essential here? I am inclined to believe that the farmers' notion is correct, namely, that the lack of potash has been occasioned by incessant cropping. At all events, that practice must have been one chief cause of the present exhaustion. In any country devoted to the rearing of stock, where the winters are so cold that cattle are kept housed during half the year and supported upon hay or other forage that has been taken off the land, much of the farm land must of necessity tend to be exhausted sooner or later, unless there should prevail a careful and thorough system of collecting and preserving the dung of the animals and of returning it to the fields, or unless a large proportion of the hay used were grown upon water-meadows. But, as is well known, no careful system of returning dung to the land has ever been generally practised in New England; and with the exception of the interval farms on our rivers, and the salt marshes of the seaboard, scarcely any land is kept in good heart by matters brought to it by water; unless, indeed, by straining a point we include in this category those favored districts where the so-called sea-manure, consisting of kelp, rock-weed, and various other sea-plants, can be procured. Hence the country has very generally come to suffer from lack of that kind of plant food which has been most completely removed. No doubt but that other matters besides potash have been removed from the land by the practices above described, or that in many instances phosphates are needed also; but the evidence would seem to show that in the present case the supply of potash originally contained in the land has given out first. It is no great matter for surprise that this thing should have occurred in a country mainly devoted to grazing and the growth of forage. If New England had been a grain-growing country, phosphoric acid might, perhaps, have been its weakest point. It is to be remembered that the conditions of New England farming are peculiar, not only in respect to the severity of the climate and to the comparative violence of the rain-fall, but that many of the methods of culture that are pursued

by our farmers are singularly unlike those which prevail upon the European farms that are most frequently described in works upon agriculture. For example, we have never in this country had anything to compare with that incessant returning of straw to the land which for a century or more was an article of faith in most of the best farming lands of Europe.* But by means of that practice the soil of many regions must have received a supply of potash that may yet endure for generations. There would be cause for surprise on most New England farms if nitrate of soda applied as a fertilizer should produce in a succession of normal seasons as good an effect, pound for pound, as nitrate of potash. Yet field experiments in Europe have not infrequently indicated such a result.

The practice of clearing land, whether of trees or bushes, by burning, which is so common in many districts, can hardly fail to hasten the process of exhaustion, inasmuch as some portions of the ashes are commonly washed into brooks and rivers by our heavy showers of rain, and because the first crops grown upon the burnt land are liable to take up and carry away a larger proportion of potash than the plants have any real need of, or than they would naturally take if the food were a little less accessible.

It is not impossible that the generality of the rocks of New England, from which the soil was formed, may contain less potash than those of more favored lands. This is a question that I mean to investigate.† But from what has been said already, it will be seen that there is no need of falling back upon a supposition such as this so long as there are well-established facts at hand by which the present lack of potash can be explained.

As regards the original poverty of our soils, the manner in which many of them have been formed, through the decomposition of the superficial layers of the great beds of loose stones, sand, and gravel with which the region is covered, cannot have been favorable to the production of a high degree of fertility. Besides the impoverishing effects produced by the mere leaching with rain-water of soils thus

* For remarks on the forms of compact between landlords and tenants, with respect to the retention of straw, see the works of William Marshall, *passim*. Compare Loudon's Encyclopædia of Agriculture; Article, Restrictive Covenants with Tenants at Will, under Rents of Leases. See also *Stoeckhardt's Chemische Feldpredigten*, I. 133, Leipzig, 1856.

† See note on p. 161.

placed upon a natural filter, it is plain that during all the earlier stages of the process of disintegration a much larger proportion of the finer particles of rock and of the matters derived from the decay of mosses and other plants must have been washed away mechanically by rain from soils overlying the drift than would usually be removed in this way from soils that were in process of formation through the decomposition of rocks in place.

In a subsequent report, it is my intention to discuss more fully the potassic manures that are obtainable hereabouts, with the view of determining which of them will probably be found most available for the New England farmer.

It has been suggested already that, on account of the liability of the soil of different divisions of a large experimental field to vary more or less in composition and character, it is neither safe nor easy to compare very closely results that have been obtained from plots not actually contiguous. But, on the other hand, it is important that the results of a considerable number of the experiments should be contrasted with one another, in the same way that those from each division of the field have been compared, in order that the rela-

---

NOTE. — Several kinds of rocks, found in place at localities in this vicinity, that have already been examined in the Bussey laboratory, contain but little potash, as will appear from the following list. I have not as yet been able to procure samples of rocks from localities to the northward, whence the drift-gravel of the Plain-field came.

	Contained per cent of potash (K_2O).
A specimen of soft clay shale, from Morton Street, Jamaica Plain, near junction with Walnut Street	1.10
A specimen of soft clay shale, from Everett, on borders of Chelsea, near corner of Chelsea Street and Everett Avenue	0.91
Rhomboidal clay slate, from quarry near old Powder-House, Elm Street, Somerville.	1.29
A compact dark-colored rock (hornblendic slate?), from Morton Street, as above. Mean of two trials . . . . . $\left\{\begin{matrix} 0.91 \\ 1.22 \end{matrix}\right\}$	1.07
A compact, fine-grained gray rock (trap?), from "red-gravel locality" on Clyde Street, Brookline	1.00
"Trap," from Chelsea Street, Everett, as above	0.68
Syenite, from Rockport, Cape Anna; piece taken from the Post-Office building in Boston	1.78
A specimen of very fine-grained granite from a quarry in Troy, N. H., at the base of Mt. Monadnock	3.66

tive positions of the several classes of fertilizers may be clearly exhibited. To this end, I have drawn up the following tables, which are analogous to those previously given, and differ from them only inasmuch as they include the results obtained from thirty squares upon several sections of the field, instead of the results from only eighteen squares upon contiguous sections. In the final large table, the merit of each fertilizer is given, not in terms of eighteenths, as before, but of thirtieths. The thirty experiments compared in these tables were selected because of the following considerations: During the years 1871 and 1872 there were cultivated, as has been seen, 72 squares of barley, 72 squares of beans, and 72 of ruta-bagas; but, as has been explained already, a number of these squares (sixteen in all for each kind of crop) were not planted in 1873. The two squares treated with green-sand in 1872 and 1873 had no manure whatever in 1871. Hence there are left only 54 squares that admit of being compared with one another for the three years, and from this number we must subtract 18, on account of the squares situated upon the fertile soil of Sections A and AA, which cannot fairly be put in comparison with the rest. From the 36 squares that are left a further deduction of 6 has been made on account of repetitions, such as the five unmanured plots, and the two sets of plots that were treated with dungs, the arithmetical means of which are taken in each case, whence the final number 30 as the basis of the comparisons.

It is to be observed that these tables have been drawn up merely for the sake of contrasting in a general way the results obtained upon different sections of the field. Care must be taken not to lay too much stress upon any of the figures, since many of them need to be qualified and explained in order that their true significance may be comprehended. Many of these explanations and qualifications, such, for example, as that the ruta-baga crops are of small significance, and that the soil of Section D was charged with elm roots, and is of rather inferior quality to that of the other sections, have been made already in connection with the tables previously given. It would be unprofitable to repeat them here. It will be enough to say, with regard to this general table, that none of the arguments and conclusions heretofore given have been derived from the consideration of it; they depend, in every instance, upon the comparison of results that had been tabulated by sections and by divisions.

In spite, however, of this lack of precision, some useful suggestions may be gathered from the general tables. The good effect of the potassic manures is noticeable almost everywhere at the first glance; and the remark applies not only to the beans, which, as has been repeatedly urged, were the only crops that have been grown with real success, but to the barley also and to the ruta-bagas. Several of the nitrogenous fertilizers did some good, particularly in 1871, when the land was in a less exhausted condition than it was afterwards. A certain useful effect was occasionally produced by some of the better superphosphates also, and this result is no matter for surprise, in view of the fact that these so-called superphosphates contained, besides phosphoric acid and nitrogen of various degrees of activity, a quantity of sulphate of lime competent to set free potash from the silicates in the soil, and some traces of potash in the animal matter of which they are in part composed.* But at the best the superphosphates have done but little, if any, more good than some of the nitrogenous manures, such as sulphate of ammonia and the heavy dressing of fish-scrap. The farm manure has done better upon barley and for the production of leaves and straw than the long horse-manure from the city, doubtless because of its containing a larger proportion of nitrogen. It will be remembered in this connection that the horse-manure used in 1872 was inferior to that of the other two years; it consisted for the most part of swale-hay.

It will be noticed, moreover, that the character of the several seasons is shown in some part by the tables which give the weights of the different crops. The summer of 1873, for example, was specially favorable for the growth of ruta-bagas, and particularly bad for the growth of barley. The summer of 1871, on the other hand, was favorable for beans and barley, but very bad for ruta-bagas.

* For example, the so-called "XL" superphosphate obtained from Mr. Wm. L. Bradley of Boston, in 1872, was found to contain 0.27 per cent of potash.

Tables showing the Best and Worst **Barley** *Crops upon the several* **Sections** *of the Field.*

Grain.						Straw.						Total Product.					
Names and numbers of squares.	Barley grain. 1871.	Names and numbers of squares.	Barley grain. 1872.	Names and numbers of squares.	Barley grain. 1873.	Names and numbers of squares.	Barley straw. 1871.	Names and numbers of squares.	Barley straw. 1872.	Names and numbers of squares.	Barley straw. 1873.	Names and numbers of squares.	Total barley crop. 1871.	Names and numbers of squares.	Total barley crop. 1872.	Names and numbers of squares.	Total barley crop. 1873.
B B 4	4.725	B B 4	2.86	B B 4	0.770	B 1	18.393	B B 4	10.14	B 1	3.272	B 1	22.25	B B 4	13.00	B B 4	3.75
B B 7	4.630	B B 7	2.65	B B 6	0.590	B 2	16.005	B 1	8.75	B B 4	2.980	B B 4	20.10	B 1	10.95	B 1	3.72
B 1	3.858	D 7	2.37	B 6	0.575	B B 4	15.375	D 7	8.38	B 2	2.262	B 2	19.30	B B 7	10.85	B 6	3.00
D 7	3.305	B 1	2.21	B B 7	0.496	B B 7	13.870	B B 7	8.20	B B 7	2.254	B B 7	18.50	D 7	10.75	B B 6	
B 2	3.295	C C 9	2.13	B 1	0.479	C C 9	12.768	B B 3	8.15	B 6	2.425	C C 9	15.25	B B 3	10.25	B B 7	2.75
D 8	3.077	B B 6	2.11	B 2	0.363	C C 2	12.432	C C 9	7.37	B B 6	2.410	C C 8	14.40	C C 9	9.50	B 2	2.62
B B 8	2.990	B B 3	2.10	C C 7	0.320	C C 8	11.653	B 6	7.24	B B 3	1.730	C C 2		B 6	9.00	B B 3	2.00
D 4	2.885	D 8	2.09	B 8	0.280	C C 4	11.525	D 4	6.97	B 4	1.491	B B 3	13.75	D 4		C C 7	1.77
C C 8	2.747	D 4	2.03	B B 3	0.270	B B 3	11.070	D 8	6.76	B 8	1.470	C C 4	13.00	D 8	8.85	B 4	1.75
B B 3	2.680	B 6	1.76	B 4	0.259	C C 7	10.610	B 8	6.40	C C 7	1.450	B B 8	12.60	C C 8	7.85	B 8	
C C 9	2.482	B 2	1.69	B 7	0.202	C 2	9.935	C C 8	6.24	B 7	1.048	D 8		B 2	7.68	B 7	1.25
B 8	2.480	C C 8	1.61	B B 8	0.162	C 3	9.633	B 2	5.99	B B 8	0.838	D 4	12.40	C C 2	7.50	B B 8	1.00
D 9	2.357	C C 2		C C 4	0.155	B B 8	9.610	C C 2	5.89	D 8	0.760	D 7	12.10	B B 6	7.00	C 2	0.91
D 2	2.190	D 1	1.36	C 2	0.150	D 3	9.588	B B 8	5.10	C 2		C C 7		B 8		D 8	0.89
B B 6	2.095	D 3	1.29	D 8	0.125	D 8	9.523	D 1	4.99	C C 4	0.695	B 8	11.25	D 1	6.35	C C 4	0.85
B 6	2.080	B 7	1.24	C C 9	0.101	D 4	9.515	B B 6	4.89	B 3	0.680	D 3	11.10	B B 8	6.15	B 3	0.75
C C 2	1.968	C 3		The 5s		C C 3	8.919	D 2	4.44	C C 2	0.645	D 2	10.50	C 3	5.65	C C 2	0.73
The 5 s.	1.628	D 6		C C 8	0.091	D 7	8.795	C 3	4.41	The 5 s.	0.627	C C 3		D 3	5.50	The 5 s.	
C C 3	1.581	B B 8	1.05	C C 2	0.085	B 8	8.770	C 2	4.35	C C 9	0.599	C 2	10.40	C 2	5.25	C C 9	0.70
B 4	1.570	C C 7		D 6	0.075	C 4	8.407	D 3	4.21	D 4	0.595	C 3	10.25	D 6		D 4	0.66
D 3	1.512	The 5 s.	0.97	B 3	0.070	D 2	8.310	B 4	4.20	D 6	0.575	D 9	10.00	D 2	5.15	D 6	0.65
C C 7	1.490	D 9	0.93	D 4	0.065	B 6	7.670	C C 7		C C 3	0.463	B 6	9.75	B 4	5.00	C C 8	0.53
C C 4	1.475	C 2	0.90	C C 3	0.052	D 9	7.643	D 6	4.01	C C 8	0.434	B B 6	9.00	The 5 s.	4.92	C C 3	0.52
D 6	1.430	C C 4	0.88	D 2	0.035	B 4	7.180	The 5 s.	3.95	D 2	0.275	C 4		C C 4	4.35	D 2	0.31
D 1	1.205	B 4	0.80	D 3	0.027	B B 6	6.905	C C 3	3.53	D 7	0.235	B 4	8.75	D 9		D 7	0.26
B 7	1.035	B 3		C 3	0.023	D 6	6.820	C C 4	3.47	C 3	0.192	D 6	8.25	C C 3	4.25	C 3	0.22
B 3	0.970	C C 3	0.72	D 7	0.020	The 5 s.	6.352	D 9	3.42	D 3	0.173	The 5 s.	7.98	B 3	4.00	D 3	0.20
C 3	0.617	D 2	0.71	D 9	0.011	D 1	4.795	B 3	3.20	D 9	0.104	D 1	6.00	B 7	3.85	D 9	0.12
C 4	0.593	B 8	0.60	D 1	0.007	B 7	4.335	C 4	2.83	D 1	0.073	B 7	5.40	C 4	3.35	D 1	0.0[illegible]
C 2	0.465	C 4	0.52	C 4	0.006	B 3	4.130	B 7	2.61	C 4	0.064	B 5	5.10			C 4	0.07

Tables showing the Best and Worst **Bean** *Crops upon the several* **Sections** *of the Field.*

Seeds.						Stalks and Leaves.						Total Product.					
Names and numbers of squares.	Bean seeds. 1871.	Names and numbers of squares.	Bean seeds. 1872.	Names and numbers of squares.	Bean seeds. 1873.	Names and numbers of squares.	Bean leaves. 1871.	Names and numbers of squares.	Bean leaves. 1872.	Names and numbers of squares.	Bean leaves. 1873.	Names and numbers of squares.	Total bean crops. 1871.	Names and numbers of squares.	Total bean crops. 1872.	Names and numbers of squares.	Total bean crops. 1873.
B 2	8.320	B B 4	6.32	B B 4	6.610	B 1	9.327	B 1	5 07	B B 4	9.976	B 2	17.50	B B 4	11.00	B B 4	16.587
B B 4	8.230	B B 7	5.76	B 2	5 874	B 2	9.180	B B 4	4 68	B 2	8 530	B 1	15.55	B 1	10.50	B 2	14.403
B B 7	7 230	B 1, B 4	5.44	B 4	4.734	B B 3	9.050	B B 7	3.74	B 1	7.526	B B 4	15.50	B B 7	9 50	B 4	12.253
B B 6	6.605	B B 6	5 19	B 7	4.612	B B 4, B B 7	7.270	B 4	3.66	B 4	7.519	B B 3	15.25	B 4	9 10	B 1	11 780
B 8	6 255	B 2	5.09	B B 6	4 561	B B 6	7.095	B B 6	3 61	B 8	7 153	B B 7	14.50	B B 6	8.80	B B 7	10 770
B 1	6.223	B 7	4.66	B 1	4 355	C C 8	6.860	B B 3	3 46	B B 7	6 448	B B 6	13.70	B B 3	7.70	B B 6	10 489
B B 3	6.200	B 8	4.29	B B 7	4 322	C C 7	6.790	B 2	3.42	D 4	6.077	B 8	12.70	B 2	7.62	D 4	9.988
B 4	4 740	B B 3	4 24	B 6	4.021	B 8	6.445	B 8	3.21	B B 6	5.928	C C 7	10.65	B 7	7.60	B 8	9.656
B 6	4.550	B 6	4.05	D 4	3 911	B 4	5.810	B 7	2.94	D 7	5 767	B 4	10 55	B 8	7.50	B 6	9 635
B B 8	4 020	D 4	3.18	D 7	3.559	C 4	5.675	B 6	2.60	B 6	5.615	C C 8	10.10	B 6	6.65	D 7	9 326
C C 7	3.860	D 7	2.29	B B 3	2.636	B 7	5.575	D 4	2.32	B B 3	5.001	B 6	9.40	D 4	5.50	B 7	8 611
D 4	3 785	B B 8	2.25	B 8	2.503	C C 9	5.115	C C 7	2.27	C C 7	4.207	B 7, C 4	9.25	C C 7	4 50	B B 3	7 637
B 7	3.675	C C 7	2.23	C C 7	1.768	B 6	4 850	C C 8	1.82	B 7	3.999	B B 8	8.60	D 7	4.00	C C 7	5.975
C 4	3.575	C 4	1 60	C C 8	0.984	C C 2	4.785	D 7	1.71	D 3	3 193	D 4	8 25	B B 8	3.90	C C 8	3.785
D 7	3.290	C C 8	1.48	B B 8	0.862	B B 8	4.580	B B 8	1.65	C C 8	2.801	D 7	7.65	C C 8	3.30	D 3	3.392
C C 8	3 240	B 3	0.93	C C 2	0 459	D 4	4.465	C 4	1.40	C C 2	2 307	C C 2	7 05	C 4	3.00	C C 2	2.766
C C 2	2 265	C 2	0.90	B 3	0.433	C 3	4 375	B 3	1.17	C C 3	2 198	C C 9	6.95	B 3	2.10	C C 3	2.363
C C 9	1.835	C C 2	0.65	D 2	0.362	D 7	4.360	C 2	1.10	D 2	1.988	C 2	5.65	C 2	2 00	D 2	2.350
C 2	1.545	D 6, The 5s	0.59	D 6	0 350	C C 4	4.115	C C 9	1.07	The 5s.	1.736	C 3	5.45	C C 2, D 6	1.65	B 3	2 137
D 6	1 415	C C 9	0.53	The 5s.	0.306	C 2	4.105	D 6	1.06	B 3	1.704	C C 3	5.15	C C 9	1.60	The 5s.	2 042
C C 3	1.290	C 3	0.29	C C 9	0.287	C C 3	3 860	C C 2	1.00	C 4	1.652	C C 4, D 6	5.10	The 5 s.	1.49	D 6	1.997
The 5 s.	1.155	D 8	0 25	D 1	0.282	D 1	3.825	The 5s.	0.90	D 6	1.647	The 5s.	4.86	C 3	1 00	D 1	1 922
C 3	1.075	D 1	0.16	C 4	0.252	The 5s.	3 705	C C 3, C C 4	0.75	D 1	1 640	D 1	4.40	C C 3	0 90	C C 9	1.909
C C 4	0.985	C C 3, D 9	0.15	C 3	0.238	D 6	3 685	C 3	0.71	C C 9	1 622	B 3	4.00	D 9	0.85	C 4	1 904
B 3	0 935	D 3	0.10	D 3	0.199	D 3	3.515	D 9	0.70	D 9	1.281	D 3	3.85	C C 4	0.80	B B 8	1.652
D 9	0 720	D 2	0.06	D 8	0.178	D 2	3.185	D 2, D 1	0.59	D 8	1 249	D 2, D 8	3.60	D 1	0.75	D 8	1.427
D 1	0.575	C C 4	0.05	C C 3	0 165	D 8	3.130	D 3	0 55	B B 8	0 790	D 9	3.35	D 8	0 70	D 9	1.415
D 8	0.470			D 9	0.134	B 3	3.065	D 8	0.45	C C 4	0.502			D 2, D 3	0.65	C C 4	0.832
D 2	0 415			C C 4	0.030	D 9	2.630										
D 3	0.335																

Tables showing the Best and Worst **Ruta-Baga** *Crops upon the several* **Sections** *of the Field.*

Roots.

Names and numbers of squares.	Ruta-Baga roots. 1871.
B 1	74.25
B B 4	63.75
B 2	59 25
B B 7	41.00
C 3	35.25
B B 6	34.50
B 8	32.25
D 6	28.25
C 2	25 75
D 7	25.25
D 2	24.00
D 4, D 9	23.25
C C 2	22.50
B 6	21.75
B 7	21.25
C C 4	21.00
B 4	19.25
D 8	17 75
C C 7	17.50
B B 8	16.50
The 5s.	15.45
D 3	14.50
B B 3	13.25
C C 8	13.00
C 4	12 75
D 1	11.25
C C 9	9.75
C C 3	8.25
B 3	7.00

Names and numbers of squares.	Ruta-baga roots. 1872.
B 6	20 00
B 1	18 63
B 2	18.38
C 2, B 8	15.00
D 7	14.50
B B 4	12.00
C C 7, B 7	11.25
C C 4	11.00
B 3, D 4	10 25
D 8	9.75
B 4, C 3	9.00
D 2	7.00
B B 6	6.25
D 9	5.75
C C 2	5.50
D 3, D 6	4.50
The 5s.	4 25
C 4	3.50
C C 8	3.25
D 1	3.00
C C 9	2 50
B B 3	2.25
C C 3	1.75
B B 8	1 50
B B 7	1.25

Names and numbers of squares.	Ruta-baga roots. 1873.
B B 4	137.25
B 2	110.36
B 1	102.36
B 6	67.50
B B 7	60.00
B 7	59 25
B B 6	52.50
B 4	47.00
B 8	22 00
C C 8	17.00
D 7	16 00
B 3, C 3	11.50
C C 4, C C 2	11.00
The 5s.	10 30
C C 7, C 2	9.00
B B 3	8.25
D 9	7.50
C C 9	7.25
D 6	6.75
D 4	5.75
D 8	4.50
B B 8	3 75
D 3	3 50
C 4	1.50
C C 3	1 25
D 2	1 00
D 1	0.25

Tops.

Names and numbers of squares.	Ruta-baga tops. 1871.
B 2	43 50
B 1	43 38
B B 4	37.50
B B 7	32.00
B B 6	30 50
B B 3	29 50
B B 8	29.25
C C 9	23.00
B 7, C C 2	22.00
D 3	21.25
C C 8, D 1	20.50
B 8, C 3	20.25
D 2	19 25
C 4	19.00
D 6	18.25
C C 3	18 00
C C 4	17.25
C C 7	17 00
B 6	14.75
D 7	14.50
C 2	14.00
B 3	13.50
The 5s.	12.90
D 9	11.00
D 4	10.00
D 8	6.50

Names and numbers of squares.	Ruta-baga tops. 1872.
B 3	17.50
C 2	16.00
B 6	15.73
B 2	14.75
B 8, C 3, C C 4	12.50
B 1	12.38
C C 7	12.25
C 4	11.50
B 7, D 9	10.25
D 3	9 75
C C 2	9.50
B B 4, D 6	9.00
B 4	8.75
D 7	8.25
D 2	8.00
C C 8, D 1	7.50
D 8	7.25
C C 9	7 00
D 4	6.75
C C 3	6.25
The 5s.	6.05
B B 6	5.25
B B 8	4.50
B B 3	2 50
B B 7	2 00

Names and numbers of squares.	Ruta-baga tops. 1873.
B B 4	34.25
B 1	27.12
B 2	26 12
B 6	19.00
B 7	17.75
B B 7	15.25
B B 6, B 4	13.75
B 8	11.75
C C 2	11.50
C 3	11 00
B B 3	10.50
C C 7	10.25
B 3, C C 8	9.50
C C 4	8.75
C 2, D 6	8.25
C C 9, D 9	7.75
D 7	6.75
The 5s.	6.60
D 3	6.25
B B 8	3.75
C C 3	3 00
D 8	2.50
D 4	2 25
C 4	2.00
D 1	0.75
D 2	0.50

Total Product.

Names and numbers of squares.	Total ruta-baga crops. 1871.
B 1	117 62
B 2	102.75
B B 4	101.25
B B 7	73 00
B B 6	65.00
C 3	55 50
B 8	52.50
D 6	46 50
B B 8	45.75
C C 2	44.50
B 7, D 2	43.25
B B 3	42.75
D 7, C 2	39.75
B 4	38.50
C C 4	38 25
B 6	33 50
D 3	35.75
C C 7	34 50
D 9	34 25
C C 8	33 50
D 4	33.25
C C 9	32.75
C 4, D 1	31 75
The 5s.	23.35
C C 3	26 25
D 8	24 25
B 3	20.50

Names and numbers of squares.	Total ruta-baga crops. 1872.
B 6	35.75
B 2	33.12
B 1, C 2	31.00
B 3	27.75
B 8	27.50
C C 7, C C 4	23.50
D 7	22 75
B 7, C 3	21.50
B B 4	21.00
B 4	17.75
D 4, D 8	17.00
D 9	16.00
D 2, C 4, C C 2	15.00
D 3	14 25
D 6	13.50
B B 6	11.50
C C 8	10.75
D 1	10 50
The 5s.	10 30
C C 9	9.50
C C 3	8.00
B B 8	6 10
B B 3	4 75
B B 7	3.25

Names and numbers of squares.	Total ruta-baga crops. 1873.
B B 4	171.50
B 2	136.50
B 1	129.50
B 6	86.50
B 7	77.00
B B 7	75.25
B B 6	66.25
B 4	60.75
B 8	33.75
C C 8	26 50
D 7	22 75
C 3, C C 2	22.50
B 3	21 00
C C 4	19.75
C C 7	19.25
B B 3	18.75
C 2	17 25
The 5s.	16.50
D 9	15.25
C C 9, D 6	15.00
D 3	9.75
D 4	8.00
B B 8	7 50
D 8	7.00
C C 3	4.25
C 4	3.50
D 2	1 50
D 1	1.00

Table of Comparative Merit of the different Kinds of Fertilizers, stated in Terms of Thirtieths.

Designations of the squares.	Kinds of fertilizers used.	Grain or Fruit.									Leaves, Stalks, or Tops.									Total Crops.								
		Barley.			Beans.			Ruta-Bagas.			Barley.			Beans.			Ruta-Bagas.			Barley.			Beans.			Ruta-Bagas.		
		1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873	1871	1872	1873
B 1 & BB 1	Farm manure, mean of the two squares . . .	3	4	5	6	3	6	1	2	3	1	2	1	1	1	3	2	6	2	1	2	2	2	2	4	1	3	3
B 2 & BB 2	City stable manure, mean of the two squares . .	5	11	6	1	5	2	3	3	2	2	12	3	2	7	2	1	4	3	3	10	5	1	7	2	2	2	2
B B 4	Wood-ashes, heavy . .	1	1	1	2	1	1	2	6	1	3	1	2	4	2	1	3	12	1	2	1	1	3	1	1	3	9	1
B 4	Wood-ashes, light . . .	20	21	10	8	3	3	17	11	8	24	21	8	9	4	4	13	13	7	20	19	8	9	4	3	14	10	8
B B 7	Sulphate of potash, heavy	2	2	4	3	2	7	4	*25	5	4	4	4	4	3	6	4	*25	6	4	3	4	5	3	5	4	*24	6
B 7	Sulphate of potash, light	26	15	11	13	6	4	15	7	6	29	*29	11	11	9	13	9	9	5	24	24	9	12	8	11	11	8	5
B B 6	Pearl-ash, heavy . . .	15	6	2	4	4	5	6	13	7	25	16	6	5	5	8	5	22	7	19	12	3	6	5	6	5	16	7
B 6	Pearl-ash, light . . .	16	10	3	9	9	8	14	1	4	22	7	5	13	10	10	19	3	4	18	7	3	11	10	9	16	1	4
D 7	Nitrate of potash . . .	4	3	26	15	11	10	10	5	11	18	3	24	18	14	9	20	14	17	11	4	22	15	13	10	13	7	11
D 2	Nitrate of soda	14	23	23	29	26	18	11	12	26	21	17	23	26	26	18	13	15	*26	14	18	21	26	*28	18	11	13	27
B B 3	Fish-scrap, heavy . . .	10	7	9	7	8	11	23	22	16	9	5	7	3	6	11	6	24	11	7	5	6	4	6	12	12	23	16
B 3	Fish-scrap, light . . .	27	21	20	25	16	17	*29	9	12	*30	27	15	28	17	20	22	1	13	*25	23	14	24	17	19	*27	4	13
B B 8	Suph. of ammonia, heavy	7	16	12	10	12	15	20	24	22	13	14	12	15	15	27	7	23	20	9	14	10	13	14	25	9	22	23
B 8	Sul. of ammonia, lighter	12	24	8	5	7	12	7	4	9	19	10	9	8	8	5	12	5	8	12	12	8	7	9	8	7	5	9
D 3	Sul. of ammonia, lightest	21	14	24	*30	25	25	22	16	23	14	20	26	25	27	14	10	10	19	13	16	24	25	*28	15	17	14	21
D 4	Sulphate of ammonia, and sulphate of potash	8	9	21	12	10	9	12	9	20	16	8	19	16	11	7	25	19	23	10	7	17	14	11	7	21	11	22
D 8	Sulphate of ammonia, and sulphate of soda .	6	8	15	28	22	26	18	10	21	15	9	13	27	*28	26	*26	17	22	9	8	12	26	27	26	26	11	24
C C 7	Bay State superphosphate	22	16	7	11	13	13	19	7	15	10	21	10	7	12	12	18	7	12	11	17	7	8	12	13	18	6	15
C C 8	Coe's superphosphate	9	12	17	16	15	14	24	19	10	7	11	22	6	13	15	11	16	13	6	9	19	10	15	14	20	17	10
C C 9	"XL" superphosphate .	11	5	16	18	20	21	27	21	18	5	6	18	12	19	24	8	18	16	5	6	16	17	20	23	22	20	20
C C 3	Wilson's superphosphate, heavy	19	22	22	21	24	27	28	23	25	17	24	21	21	23	17	16	20	21	14	22	20	20	23	17	25	21	25
C 3	Wilson's superphosphate, light.	28	15	25	23	21	24	5	11	12	12	18	25	17	24	..	12	5	10	16	15	23	19	22	..	6	8	12
C 4	Crushed bone	29	*25	*29	14	14	23	25	18	24	20	28	*29	10	16	21	14	8	24	19	*25	*27	12	16	24	23	13	26
C C 4	Flour of bone	23	20	13	24	*27	*29	16	8	13	8	25	14	19	23	*28	17	5	14	8	21	13	21	25	*28	15	6	14
C C 2	Peruvian guano, heavy .	17	12	18	17	8	16	13	15	13	6	13	16	14	21	16	9	11	9	6	11	15	16	19	16	10	13	12
C 2	Peruvian guano, light .	*30	19	14	19	17	..	9	4	15	11	19	13	20	18	..	21	2	15	15	17	11	18	18	..	13	3	17
D 6	Chloride of ammonium .	24	15	19	20	19	19	8	16	19	26	22	20	24	20	22	15	12	15	21	17	18	21	19	21	8	15	20
D 1	Nitrate of ammonia . .	25	13	28	27	23	22	26	20	*27	28	15	28	22	26	23	11	16	25	23	13	26	23	26	22	23	18	*28
D 9	Carbonate of ammonia .	13	18	27	26	24	28	12	14	17	23	26	27	*29	25	25	24	9	16	17	21	25	*27	24	27	19	12	19
Mean of the 5 s.	No manure, mean of the five squares	18	17	16	22	19	20	21	17	14	27	23	17	23	22	19	23	21	18	22	20	15	22	21	20	24	19	18

As was naturally to be expected, the results of these experiments made upon poor land are very different from those of a great number of field experiments that have been made in Europe. It is not always that the needs of a given soil are indicated as clearly as in this instance. In the records of scientific agriculture there may be found the details of many experiments in which the plots of unmanured land yielded as good crops or almost as good as those that had been heavily dressed with all kinds of fertilizers; and this to all appearance, not because of excessive drought or wetness, but because of the original fertility of the land. It seems often to be the case upon European fields that this particular condition (natural fertility) is in excess, so to speak, of the other conditions that are essential for the successful growth of crops. Such experiments illustrate very clearly the great differences which subsist between the agriculture of those countries and that of our own. It is plain that upon the rich European farms comparatively little thought is bestowed upon the natural strength of the soil. But with us, where land is cheap and abundant, it is inevitable, and it is proper, that the farmer should endeavor to derive the utmost possible advantage from the matters naturally contained in his land. It may be said, indeed, speaking in general terms and of the generality of instances, as they exist in this region, that that man will be the best farmer who knows how to use the natural force of his land most fully, without injuring or in any way weakening it, and who, if need be, can, slowly perhaps, but with constant profit to himself, increase the original fertility until it is in complete accord with the other conditions and circumstances by which the profits of the farm are limited and controlled. But in many of the better parts of Europe the case is different. There the problem for the farmer to solve might almost be said to be: — given standing-room, how to get the largest possible yield from the land? And the more costly and fertile the land happens to be, so much the stronger would seem to be the tendency to manure it heavily, and to employ the most concentrated manures, with the view of obtaining a little larger return than could otherwise be got from the great reservoir of plant-food, which the land must of itself be considered to be. Such practices depend, of course, in good part, upon various social, economic, and political considerations with which the chemist has no particular concern; but from a cosmopolitan point of view, it

is hard to believe that the practice of drenching rich land with dung, and with manures that are in some sort complete, can be truly philosophical so long as there are vast tracts of land all over the world still waiting to be tilled. It is undoubtedly true that, during the last twenty or thirty years, much intelligent action has been brought to bear upon the question how best to use all the available sources of plant-food, and that many European farmers now utilize the natural fertility of their land more fully than was formerly the case, notably by manuring with active nitrogen compounds and with superphosphate. But there would still seem to be room for improvement in that regard. It would be exceedingly interesting to learn how many European farmers have intelligently sought, in the light of Messrs. Lawes and Gilbert's famous research,* to use up to the point of economic completeness any excessive store of either kind of plant-food that their land may have contained naturally, or which may have accumulated in the land through the application of straw and dung continued for long terms of years, and to know with what measure of success the effort has been attended.

It is evident that experiments made upon the fertile European soils, like many of the practices of the farmers who till them, can have but little direct application for the solution of problems that present themselves in New England. On examining the records of a large number of German experiments, I have been surprised to find how small a proportion of them were made upon really poor land. Some of them, indeed, as has just been indicated, have served merely to point out the danger of adopting too intense a system of cultivation, inasmuch as neither nitrogenous, phosphatic, nor potassic manures gave any increase over the abundant crops obtained from the plots that were left unmanured. In most of these cases the soils were doubtless in the same predicament as those squares of my own experiments that were heavily dressed with mixed fertilizers; that is to say, they contained an excess of all kinds of plant-food over and above what the crops could make use of under the conditions to which the land was exposed. Many of the European experiments would undoubtedly have given more useful results, even as regards the land upon which they were made, if the fertility of the soil had

* Report of Experiments on the Growth of Wheat for Twenty Years in Succession, on the same Land, by J. B. Lawes and J. H. Gilbert, London, 1864.

first been reduced somewhat by the removal of a succession of crops grown without addition of any manure. Compare, for example, a set of Bavarian experiments reported by Fraas (*Hoffman's Jahresbericht*, **2**, 143), in which this idea was put in practice.

No. 8. — *Analyses of several Foreign Superphosphates of Lime; with Remarks on the Cost of importing Superphosphates from Europe.* By F. H. Storer, Professor of Agricultural Chemistry.

An attempt recently made by the Trustees of the Massachusetts Society for Promoting Agriculture, to determine whether it would be practicable, economically speaking, for American farmers to import superphosphate of lime from Europe, led to the following analyses of samples of that substance: —

I. A sample given to the Massachusetts Society for Promoting Agriculture by Mr. Lawes of Rothamsted, England (see his letter on page 181).

Of matters valuable as manure the specimen contained: —

Phosphoric acid soluble in water	8.31%	
" " insoluble " . . .	1.63	
Total		9.94%

The specimen gave off 15.33% of moisture when heated to 212°.

II. A sample warranted to contain 10% of soluble phosphoric acid, bought of Dr. L. C. Marquart, in Bonn, Germany.

Phosphoric acid soluble in water	7.79%	
" " insoluble " . . .	5.58	
Total		13.37%

The specimen gave off 13.07% of moisture when heated to 212°, and left 71.10% of ash on being ignited.

III. A sample warranted to contain 15% of soluble phosphoric acid, bought of Dr. Marquart of Bonn.

Phosphoric acid soluble in water	14.19%	
" " insoluble " . . .	1.58	
Total		15.77%

The specimen gave off 20.06% of moisture at 212°, and left 58.60% of ash when ignited. It contained 3.47% of sand, etc., insoluble in acid.

IV. A sample warranted to contain 20% of soluble phosphoric acid, bought of Dr. Marquart of Bonn.

Phosphoric acid soluble in water	17.86%
" " insoluble "	1.56
Total	19.42%

The specimen gave off 18.47% of moisture at 212°, left 60.15% of ash when ignited, and contained 1.59% of sand insoluble in acid.

Another analysis of No. IV., made three months later than the first, gave —

Phosphoric acid soluble in water	17.83%
" " insoluble "	1.29
Total	19.12%

The two following samples (Nos. V. and VI.) were analyzed on the supposition that they were of better quality than most of the fertilizers on sale in this vicinity, in the hope of finding a really good domestic product to compare with the foreign article. It will be seen, however, on comparing the analyses with those of other American fertilizers examined in this laboratory (pages 8 – 15), that this anticipation was disappointed, and that the Portland samples belong to the same general class or family as those previously procured in Boston.

V. "Cumberland superphosphate," from Portland, Maine, obtained in the spring of 1873 by J. R. Brewer, Esq., of Hingham.

Moisture expelled at 212°	21.54%	
Volatile matter (beside moisture)	32.15	
Ash	46.31	
		100.00

Of matters valuable as manure the specimen contained: —

Soluble phosphoric acid.	4.98%
Insoluble " "	6.86
Total " "	11.84%
Nitrogen	2.19%
There was no ammonia; but sand, etc., to the amount of .	6.38%

VI. "Cumberland ammoniated bone," from Portland, Maine, obtained in the spring of 1873 by J. R. Brewer, Esq., of Hingham.

Moisture	14.71%	
Volatile matter (beside moisture)	34.13	
Ash	51.16	
		100.00

Of matters valuable as manure the specimen contained: —

Soluble phosphoric acid	0.38%	
Insoluble " "	18.28	
Total " "		18.66%

Total nitrogen, 3.11% = { ammonia, 1.42%, i. e. nitrogen 1.17%; nitrogen not in form of ammonia 1.94 } —— 3.11%

There was sand, etc., insoluble in acid, to the amount of . . 2.51%

In October, 1872, $55 per ton was asked in Boston for the Cumberland superphosphate, and $50 per ton for the Cumberland ammoniated bone; and a considerable discount upon these sums was granted in the spring of 1873 to the purchaser of a car-load of the materials who dealt directly with the manufacturer, and was allowed the commission that would ordinarily have been paid to the selling agent.

One of the samples (No. II.) obtained from Dr. Marquart had evidently deteriorated by keeping; that is to say, a portion of the soluble phosphoric acid originally contained in it had undoubtedly been "reduced" since the time of manufacture. The analysis goes to show that the low-grade European superphosphates, like most of those made in this country, should be brought to the land fresh from the manufactory, in order that the crops to which they are applied may derive the full benefit of the labor and chemical treatment which have been expended to that end by the manufacturer of the fertilizer. The other samples from Dr. Marquart (Nos. III. and IV.) were doubtless what they purported to be, though the analyses do not show it. Through the carelessness of the European shipper, these high-grade samples were put into the hold of a sailing-vessel for the Atlantic voyage in coarse bags. Naturally enough, the bags were found to be thoroughly rotten when the ship was discharged; and it is evident from the analyses that a good deal of moisture had been absorbed by the hygroscopic materials. But the presence of this extraneous moisture of course lowers the percentage proportion of phosphoric acid, as shown by analysis. On subtracting the excess of moisture, the proportion of soluble phosphoric acid rises at once to the amount that was guaranteed. There is consequently

good reason for believing that both of the high-grade samples were really what they pretended to be. For example, we have only to assume that No. III. contained 14% of moisture at the time when it was bought, and that No. IV. contained between 8% and 9%, in order that the amounts of soluble phosphoric acid found in the samples shall accord with the warranted quantities. The absorption of 6% of moisture in the one case, and of 10% in the other, would debase the 15% superphosphate to 14%, and the 20% article to less than 18%. The doubt and uncertainty occasioned by this absorption of water, and a part of the expense incurred at Boston in transferring the superphosphates from the rotten bags to barrels, would, of course, have been avoided if the samples had been packed in tight kegs or casks in the first instance. Even the lower grade samples (Nos. I. and II.) may have deteriorated somewhat through absorption of water. At all events, the amount of moisture found in them would seem to be unduly large. The superphosphate obtained from Mr. Lawes was properly packed in casks for the voyage; but the sample analyzed had been a good deal exposed to the air after the casks were opened before it reached the laboratory.

It will be noticed that in the high-grade samples (Nos. III. and IV.) but little, if any, of the soluble phosphoric acid has "gone back" or been "reduced" to the insoluble state. In neither instance is the amount of insoluble phosphoric acid larger than would be likely to occur in fresh samples. The fact that so little of it has been found in these specimens is a good indication of their excellence.

The prices paid for these superphosphates in Europe, and the cost of transporting them to this country, will appear from the following statements, which have been drawn up by Mr. Henry Saltonstall, Treasurer of the Massachusetts Society for Promoting Agriculture: —

Actual Cost of Three Tons German Superphosphate, from Dr. L. Marquart, of Bonn, via Rotterdam, to Boston, June, 1873.

			s. d.	£ s. d.	
S. I.	20 Bales,	10% @	6 3	6 5 0	
S. II.	20 "	15% @	8 4	8 6 8	
S. III.	20 "	20% @	10 6	10 10 0	
Paid Dr. Marquart				25 1 8	or florins, 305.00

Charges at Rotterdam.

Shipping charges and postage, 7.50; Consul's fees, 6.25; Commission, 2% = 6.10			19.85
Florins			324.85

Final Payment at Boston.

324.85 florins at 48 cents per florin		$155.93	
Interest on same, 2 months 22 days	2.48		
75 days' interest on remittance	2.27		
		4.75	
Custom-house fees		1.50	
Freight and primage from Rotterdam		38.98	
Boston wharf charges		6.00	
29 empty barrels, repacking and cooperage		16.20	
Lewis Wharf, for storage and labor		4.80	
Total		$ 228.16	currency.

Proportionate cost of 10% = $ 62.52 per ton.
" " " 15% = 75.88 " "
" " " 20% = 89.76 " "

The foregoing statement represents the cost of importing German superphosphate under extremely disadvantageous circumstances. Dr. Marquart is a manufacturer of fine chemicals. He neither makes nor deals in superphosphates. The Massachusetts Society applied to him in this instance merely because of the good standing of his house, and because he was known to be in the habit of shipping goods to Boston. He, of course, charged such profit as pleased him for his trouble in procuring and forwarding the material. Part of the cost of handling the superphosphate in Boston could be avoided in future by having it properly packed at the factory. Since the importation was made, I have obtained the price-list of Emil Güssefeld of Hamburg, a firm devoted to the manufacture of superphosphates and the importation of phosphatic materials, such as Baker Island guano, and the like. From this list it appears that the prices of warranted superphosphates corresponding to Nos. III. and IV., above described, were as follows at Hamburg in the summer and autumn of 1873: The price of an article made from Baker Island guano, and warranted to contain 20% of soluble phosphoric acid, was from $2\frac{5}{6}$ to 3 courant thalers per 110 pounds English, according to the quantity taken; while the price of an article made from "mineral phosphate," and containing 15% soluble phosphoric acid, plus 1% or 2% of insoluble phosphoric acid, was from $2\frac{1}{3}$ to $2\frac{1}{4}$ thalers per 110 pounds. These

prices refer to the gross weight of the superphosphate packed in bags. In case casks are ordered, 6% is allowed for tare. Among the various other products advertised by Güssefeld, an 18% article made from Baker Island guano, at $2\frac{1}{2}$ to $2\frac{3}{4}$ thalers, and a 19% ditto, at $2\frac{2}{3}$ to $2\frac{7}{8}$ thalers, are noteworthy.

From these data, and the experience gained by the actual importation of June, 1873, Mr. Saltonstall has drawn up the following estimate: —

Estimated Cost of importing Ten Tons German Superphosphate from Hamburg by Sailing-Vessel to Boston.

10 tons, guaranteed to contain 20% soluble phosphoric acid, @ 3 Prussian thalers for 100 lbs. German, or 61 Prussian thalers for 2,240 lbs. English = 610 thalers @ $72\frac{1}{2}$ cents each . . .	$ 442.25
Say 70 barrels (about 300 lbs. in each) @ $\frac{1}{2}$ thaler each, or $36\frac{1}{4}$ cents	25.38
Shipping charges, consul's fees, postage, and commission, say . .	15.00
	482.63
Freight and primage to Boston @ say 30*s.* per ton = £ 15 @ $ 4.90	73.50
	$ 556.13

$ 556.13 gold @ 13% premium = $ 628.43 currency.

Boston Charges.

Custom-house fees and wharfage, say . .	25.00
	$ 653.43 currency,

or $ 65.34 per ton on wharf in Boston.

Allowing all charges, except first cost, to remain the same as above, and substituting $2\frac{3}{4}$ thalers per cwt. for 18%, and $2\frac{1}{4}$ thalers per cwt. for 15%, then
10 tons of 18% should cost, landed, say $ 61.25 per ton currency, and
10 " " 15% " " " " 52. 84 " " "

From this estimate, it appears that the 448 pounds of soluble phosphoric acid contained in a ton of the 20% article may be landed in Boston for $ $65\frac{1}{3}$, the 403 pounds in a ton of the 18% article for $ $61\frac{1}{4}$, and the 336 pounds in a ton of the 15% article for $ 53; that is to say, the soluble phosphoric acid would cost us $14\frac{1}{2}$ cents per pound in the 20% article, $15\frac{1}{4}$ cents in the 18%, and about $15\frac{3}{4}$ cents in that of 15%. There would naturally be a certain advantage in importing the higher grade samples, since the transportation of a ton of the best material will cost no more than the transport of a ton of the worst; and, in fact, it appears from the estimate that, while the price at Hamburg of any given quantity of soluble phosphoric acid is

very nearly the same (10 cents per pound) whether it be contained in the highest grade samples or in those of the lower grades, something may be saved in respect to freight by avoiding the transportation of the impurities with which the lower grades are admixed.

The cost of importing superphosphates from England will appear from the following statements and estimates. It will be noticed that the first statement refers to an actual importation : —

Estimated Cost of Lawes's Superphosphate shipped from London to Liverpool, and thence by Steamer to Boston, based on Costs of actual Importation of March, 1873.

	£	s.	d.
3 tons invoiced at £ 4 per ton delivered	12	0	0
7 casks @ 5 s. each	1	15	0
	13	15	0
Paid at Liverpool : —			
Customs dues, 1 s. 9 d.; Entry fees, 1 s. 6 d.; Bills lading, 2 s. 6 d.; Postage, 4 d.; Cartage, 19 s.; Coopering, 16 s. 4 d.; Freight from London, £ 1 17 s. 8 d.; Commissions, 10 s. 6 d. . . .	4	9	7
Freight and primage to Boston, £ 6 5 s. 2 d., or, say £ 2 1 s. 9 d. per ton	6	5	2
	£ 24	9	9

Cost in Currency as follows.

Estimated value of £ 13 15 s. @ 9½% exchange and 18% gold . .	$ 78.93
Paid Kidder, Peabody, & Co. for £ 4 9 s. 7 d.	25.64
" Cunard Steamship Co. for £ 6 5s. 2d. @ 29⅝% exc. and gold	35.99

Boston Charges.

Steamer charges, 87 cents; Custom-house and entry fees, $ 1.10; Appraiser's and storage fees, $ 9.45	11.42
Total, say $ 50.66 per ton, or	$ 151.98

The casks were discharged from the steamer before they could be entered, and were taken to the United States storehouse, where they were allowed to stay one month.

The foregoing statement represents the extreme cost of importing English superphosphate. The sample came by steamer, and it had to bear the cost of transportation from London to Liverpool. A very considerable saving could, of course, be made by shipping directly from London to Boston by sailing-vessel, as will be seen by referring to the statement on page 179.

Since the lot of superphosphate sent to the Trustees of the Massachusetts Society by Mr. Lawes was a gift, the price at which it was

invoiced did not necessarily indicate that at which an article of similar quality could be bought in London. Doubts were, in fact, suggested in certain quarters as to the justice of Mr. Saltonstall's premise in the foregoing computations that £4 was the London price. In order to settle this point definitively, application was made to Mr. F. H. Appleton of West Peabody, since elected an officer of this institution, who happened to be in England in September, 1873, that he should put himself into communication with several English manufacturers of superphosphates, and ascertain the prices at which the products of their establishments are habitually sold. The data obtained by Mr. Appleton are given in the table on the following page. It will be seen that they fully corroborate Mr. Saltonstall's statement.

Prices asked for Superphosphates by English Manufacturers.

Names and Localities of Manufacturers.	Percentage of "*phosphate made soluble*" * contained in the fertilizer.	Percentage of *soluble phosphoric acid*, corresponding to the foregoing amount of "phosphate made soluble."	Price † per ton of 2,240 lbs. (September, 1873).
James Gibbs & Co., London . . . / Arnott Bros. & Co., London and Liverpool	25	11.56	. . . . £4 1^s 6^d ‡ / . . . . £4 5^s §
Odams's Chemical Manure Co., Plaistow and London	25 ("30% total phosphates, of which not less than 25% is made soluble")	11.56	. . . . £3 10^s §
Lawes Chemical Manure Co., London	28 – 30 ¶	12.92 – 13.85	. . . . £3 15^s ‖
Odams's Chemical Manure Co., Plaistow and London	28 – 35 (made from mineral phosphate)	12.92 – 16.15	3^s 3^d per unit, i.e. £4 11^s to £5 13^s 9^d §
Henry Richardson & Co., York .	35 (made from mineral phosphate)	16.15	. . . . £5 15^s
James Gibbs & Co., London . . .	35 – 38 **	16.15 – 17.54	. . . . £5 15^s 6^d ‡
Odams's Chemical Manure Co., Plaistow and London	35 – 40 (made from bone) . . .	16.15 – 18.46	3^s 9^d per unit, i.e. £6 11^s 3^d to £7 10^s §
Henry Richardson & Co., York . .	36 – 37 (made from bone, and containing 4 – 6% insol. phosphate)	16.61 – 17.07	. . . . £6 12^s 6^d
Edward Packard & Co., Ipswich .	upwards of 38 (and 5% of insoluble phosphates also) .	17.54	. . . . £6 17^s 6^d ‡
Arnott Bros. & Co., London and Liverpool	"Superphosphate from bone-ash" ††	. . . . .	. . . . £7 §

NOTE. — It will be remarked that several of the superphosphates that are esteemed to be of low grade in Europe are warranted by their manufacturers to contain an amount of soluble phosphoric acid that is actually larger than can ordinarily be found in the most costly of our American fertilizers.

* In the English market, superphosphates are ordinarily bought and sold on a basis of "phosphate made soluble"; that is to say, on the amount of $3\,CaO, P_2O_5$ that has been fully decomposed in the process of manufacture or converted into $CaO, 2\,H_2O, P_2O_5$, as shown by analysis. The German custom of referring the value of a superphosphate to the amount of soluble phosphoric acid (P_2O_5) that is contained in it is preferable on many accounts.

† Several of the manufacturers make a discount of from 2½ to 5 per cent for cash, and others allow "agent's commission" to persons purchasing at the works.

‡ In bags, free on board ship. § In bulk, free on board ship. ‖ In bulk, delivered on wharf at the works.

¶ In case the fertilizer should happen to fall below the standard of 28 per cent of "phosphate made soluble," an allowance is made to the buyer by the Lawes Co. But if, on the contrary, analysis should show that the sample contains more than 28 per cent, a similar allowance is to be paid to the company.

** Messrs. Gibbs & Co. stipulate for a tolerance of 2 per cent on the warranted amount of phosphate made soluble, "to allow for difference in chemist's analysis."

†† Many of the higher grade English superphosphates are said to be made from bone-ash. It is possible to make an article containing as much as 18 or 19 per cent of soluble phosphoric acid from this material.

In the light of this information, Mr. Saltonstall has prepared the following estimate of the cost of importing superphosphate from England : —

Estimated Cost of importing Ten Tons of Lawes's Superphosphate direct from London, by Sailing-Vessel to Boston.

	£	s.	d.
10 tons superphosphate @ £ 4 per ton delivered	40	0	0
Say 30 casks @ 5 *s.* each	7	10	0
Customs dues, entry permit, and bills of lading		10	0
Freight and primage to Boston say 25 *s.* per ton . . .	12	10	0
	60	10	0

@ say $ 4.90 per pound sterling, and 13% on gold	$ 335.00
Boston wharfage and custom-house fees, say . .	25.00
Total	$ 360.00 currency,

or $ 36 per ton on wharf in Boston.

The estimated cost on above basis of a higher grade superphosphate, all charges other than first cost being the same, may be found by adding to $ 36 per ton say 28 cents for every shilling per ton cost in England over £ 4 delivered. For example, a superphosphate costing £ 4 10 *s.* delivered to ship in London or Liverpool, should cost say $ 38.80 per ton on wharf in Boston.

It appears from the table that in England, contrary to what the price-list of Güssefeld and the invoice of Marquart show to be true for Germany, the price of any given quantity of soluble phosphoric acid is somewhat higher in the high-grade articles than in those of low grade. Thus the 291 pounds of soluble phosphoric acid contained in a ton of the 13% article, sold by the Lawes Chemical Manure Company at £ 3 15 *s.*, would cost in England * about $ 20.63, or a single pound about 7 cents ; while the 358 pounds contained in a ton of the 16% article, at £ 5 15 *s.*, would cost about $ 31.63, or nearly 9 cents per pound ; and the 400 pounds contained in a ton of the 18% article, at, say £ 7 10 *s.*, would cost about $ 41.25, or rather more than 10 cents per pound. It appears, in fact, that the difference between the first cost of the 13% article and those of higher grade is more than sufficient to make up for the expense of transporting the inert materials which are contained in the 13% superphosphate. On referring to Mr. Saltonstall's estimate, it will be seen that the cost per ton on wharf at Boston of each of the three grades of superphosphate now under discussion would be $ 36 for the 13%, $ 45.80 for the 16%, and $ 55 60 for the 18% ; that is to say, the cost per

* Taking 27½ cents of our money as the equivalent of an English shilling.

pound of soluble phosphoric acid would be about 12⅓ cents in the 13% article, almost 13 cents in that of 16%, and nearly 14 cents in that of 18%. It will be well, however, for the American importer of superphosphate to remember that the articles of high grade are more trustworthy than those of low price, and that the liability of the low-grade superphosphates to deteriorate by keeping is a serious objection to the importation of such material. Neither the seller nor the buyer could be perfectly sure as to the state in which a low-grade superphosphate might arrive in this country. It would be hard to estimate how much of the original soluble phosphoric acid would be left in any given sample at the end of a long voyage. High-grade superphosphates, on the contrary, carefully made from pure materials, may be kept without detriment for any length of time.

It appears from the foregoing that soluble phosphoric acid can be brought hither both from England and from Germany at a much lower price than it can usually be bought for in Boston. In other words, it may be regarded as proved that any society or combination of farmers could procure trustworthy superphosphates from abroad at decidedly lower rates than those customarily paid in this market for fertilizers of indifferent and uncertain quality. Much good could undoubtedly be done by any agricultural society that would undertake the importation of warranted high-grade superphosphate, not with a view of profiting by the sale of the material, and even at the risk of a considerable money loss, solely for the purpose of establishing in this community a definite standard of excellence in that particular, and of enabling our farmers to try for once what effect would be produced upon their land by a real superphosphate.

The difficulty in organizing such action as has just been proposed is not a material one, but there are certain moral considerations which greatly embarrass the project. Were it not for a certain feeling or sentiment which prevails in this community, that the pure fertilizers so much desired could and should be made here, steps would undoubtedly have been taken ere this to procure them from abroad; but the moment it is shown, by an exhibition of the prices at which superphosphates are sold in Europe, that the cost of manufacturing these products must be, comparatively speaking, small, almost every one is overpowered by a conviction that the fertilizers could

be made in this country more cheaply than they can be imported, and that they should be so made directly. It was this impression, doubtless, that led Mr. Lawes to write the following letter, which he sent to the Massachusetts Society with his gift of superphosphate : —

ROTHAMSTED, ST. ALBANS, March 25, 1873.

HENRY SALTONSTALL, ESQ., *Treasurer Massachusetts Society for Promoting Agriculture.*

DEAR SIR, — Dr. Gilbert has requested me to answer your letter of the 21st of January, and to inform you that, in accordance with your request, I have forwarded to you, through Messrs. Saunders & Co., Liverpool, three tons of superphosphate of lime. I am very sorry that so much delay has taken place in this matter ; but it was found necessary to have the manure packed in casks, and these casks caused delay in the order. I have for some time ceased to be a manufacturer of commercial manure, and therefore had not the same authority as formerly. The manures I have forwarded to you are made entirely from Charleston phosphate and sulphuric acid. I have selected this substance in preference to our own phosphate, in order to prove to you that you have one of the best phosphates which the world produces, but also one which can yield a commercial superphosphate cheaper than any other. Charleston phosphate, as imported into this country, contains from 57 to 60 per cent of phosphate of lime. When ground and mixed with sulphuric acid (sp. gr. 1.6), in the proportion of 100 phosphate to about 80 acid, it yields a product of 30 to 33 phosphate rendered soluble, and not more than 3 to 4 per cent insoluble. In your country the phosphate can be raised at a cost of less than 20 *s.* per ton. The grinding would cost, at the most, 5 *s.* per ton ; the acid 50 *s.* per ton. In fact, the net cost of the superphosphate, ready to pack into bags, ought not be more than 40 *s.* per ton of 2,240 pounds ; and all the phosphoric acid should be rendered soluble except 2 or 3 per cent. As these manures are required for experimental purposes, I beg to offer them to the Massachusetts Agricultural Society without charge, and also the following summary, which may be said to comprise the results of my experience and practice in regard to artificial manures for the last thirty years : —

The only two substances really required in artificial manures are, —

1st. Nitrogen ;

2d. Phosphate of lime.

Nitrogen is useful in three forms, —

1st. As nitric acid ;

2d. As ammonia ;

3d. As organic decomposable matter, yielding ammonia or nitric acid.

Nitrogen is more valuable in the form of nitric acid than it is as ammonia, and ammonia is more valuable than decaying substances yielding it. The

best possible manure for all graminaceous crops — wheat, barley, maize, oats, sugar-cane, rice, pasture, grass — is a mixture of superphosphate of lime and nitrate of soda. Three hundred pounds of superphosphate of lime and 275 pounds of nitrate of soda applied every year to one acre of ordinary English land has for twenty consecutive years given a produce annually of six quarters of barley. Fourteen tons of farm-yard dung applied annually over the same period has given the same produce of barley. Superphosphate of lime is a special chemical manufacture which can be made cheaper on a large than on a small scale, and therefore farmers ought to purchase it cheaper than they can make it; but it is better to make up their own compound manures, purchasing their nitrate of soda or salts of ammonia. It is not advisable to sow artificial manure with beans, peas, tares, or other leguminous plants. Corn [i. e. grain] and root crops will take all the artificial manure which the farmer can afford to pay for. Superphosphate of lime should always be placed under the soil, either by drilling or harrowing in when the seed is sown. Nitrate of soda may be sown in the same way, or it may be sown broadcast when the crop is up. The increase in the growth of the cereal crop is much more dependent upon the nitrogen supplied than on the phosphoric acid. Potash is generally found in sufficient quantities in soils, and the artificial supply is not required. J. B. LAWES.

I have no doubt but that if there were any widespread, intelligent demand for high-grade superphosphates in this country, these fertilizers could be manufactured here and sold at a profit for less money than it would cost to import them; but in point of fact there is no such demand, and there never will be until the consumer has learnt in one way or another that it would be for his advantage to procure such materials, and to avoid those that cost more than they are worth. It is precisely for the purpose of diffusing sound knowledge, and of exciting a just demand, that the foreign superphosphates should be imported by our societies. It is idle to expect the American manufacturers of fertilizers to materially change their methods and processes so long as they can find a ready market for inferior products, that can be manufactured at comparatively small cost and sold at high prices.

The publication of Mr. Lawes's letter soon after its arrival in this country, in the spring of 1873, led to various adverse criticisms, some of which were manifestly unjust. It was objected that Mr. Lawes's estimate of the cost of raising phosphate-rock must be incorrect, since experience had taught that the material could not be bought in

Charleston, much less be bought and transported to our Northern cities, for the sum mentioned; but it is to be observed that Mr. Lawes is not writing in the interest of the New England manufacturer. His words point most distinctly to a manufactory in the immediate vicinity of the phosphate-beds, perhaps even worked by the proprietor of a phosphate-bed. His views are evidently those of a large English manufacturer, familiar with extensive operations resting on firm bases. It was maintained, moreover, that the cost of making sulphuric acid in this country must be very much larger than the cost of that manufacture as stated by Mr. Lawes, because oil of vitriol* could not be bought in our markets except at a much higher price; but Mr. Lawes is speaking of the cost of making acid for use, not for sale, and, moreover, he says nothing of oil of vitriol.

From the printed price-list of the Lawes Chemical Manure Company, obtained by Mr. Appleton, it would appear that the sale-price of sulphuric acid is not very much lower in England than in this country. In September, 1873, the Lawes Company advertised sulphuric acid of 1.7 sp. gr. at $\frac{3}{4}$ of a penny per pound, or $1\frac{7}{10}$ cents of our money, estimating the pound sterling at $4.90, and the premium on gold at 13%; but during the summer of 1873 oil of vitriol could be bought by the large quantity in Boston for $1\frac{3}{4}$ cents per pound. I was informed at that time by one large consumer of this material in Boston, that he had been supplied for some months at the rate of $1\frac{1}{2}$ cents per pound, though it was generally supposed that the manufacturer gained no direct profit by selling at that price.

Morfit, in his work entitled "A Practical Treatise on Pure Fertilizers" (New York, 1872), page 503, when describing the manufacture (in England) of a very high-grade superphosphate, specifies, among other things needed, a number of tons of sulphuric acid of 1.7 sp. gr., at 70 *s.* per ton; that is to say, he estimates the cost of such acid to the superphosphate-maker at something less than 1 cent per pound. But the acid of 1.6 sp. gr. mentioned in Mr. Lawes's letter is a weaker and a cheaper article than this. Even if it should appear that Mr. Lawes's estimate of the cost of making sulphuric acid in this country is very far from the truth, his statement would still be valuable as

* Through a misunderstanding, Mr. Lawes's statement of the strength of the sulphuric acid referred to in his estimate was left out when the letter was first printed. His original manuscript reads, "Sulphuric acid, sp. gr. 1.6," as printed above.

indicating, no matter how roughly, what can be done in this respect in England. In case it could be shown that our manufacturers are quite unable to compete with those of England in this branch of manufacture, there might be ground for arguing that we had better obtain our entire supply of superphosphate from Europe.

Mr. Lawes's advice to farmers that they should purchase fertilizers singly, — that is to say, in the uncompounded state, — and mix them for themselves when mixtures are needed, is a point that cannot be too strongly urged in this country. All that could be said as to the inadvisability of buying mixtures of superphosphate and nitrate of soda or sulphate of ammonia may be urged with still greater force against the mixtures of superphosphate and rough nitrogenous matters, such as fish-scrap or slaughter-house refuse, that are so common in the American markets. The farmer can buy these nitrogenous fertilizers by themselves at cheap rates; and it will unquestionably be well for him to do so, especially since it has been shown that pure superphosphates can readily be procured from Europe.

Some of the other recommendations of Mr. Lawes will hardly be found to meet the requirements of most soils in this vicinity. Thus, his proposal to use nitrate of soda at the rate of two hundred and seventy-five pounds to the acre, his omission of potash from the mixture of fertilizers, and his remark as to the inutility of putting potash upon land apply, of course, only to the soils of fertile regions, or to soils derived from rocks rich in potash. It has long been known that the soils of New England stand in great and special need of potash, as has been set forth at some length in this Bulletin, pages 155 – 161.

No. 9.— *On the Valuation of the Soluble Phosphoric Acid in Superphosphate of Lime.* By F. H. Storer, Professor of Agricultural Chemistry.

In calculating the value of a superphosphate from the consumer's point of view, it has hitherto been difficult to determine, even approximately, what price should be allowed per pound in this vicinity for the soluble phosphoric acid.

In the nature of things, it is less easy to form a just estimate of the average value of the constituents of a manufactured article like superphosphate of lime, than of those of a waste product, like the siftings of bone-black, or of a raw material like bone-ash. The prices of the substances last named are controlled by the simplest laws of trade, and they are consequently, comparatively speaking, definite and well known, and subject to no great fluctuations. But the price and composition of bone-ash, and of spent bone-black, having been determined, the price of the insoluble phosphoric acid contained in these materials follows as a matter of course, as has been set forth on page 17 of this "Bulletin." So, too, the price per pound that the farmer must pay at the present time for potash rests directly upon a firm and definite basis; viz., the price of "muriate of potash" imported from Germany.* But with respect

* In January–February, 1874, muriate of potash, containing 80% of the pure salt (KCl), was sold in Boston at $55.00 currency per ton, a price that would be equivalent to about 5½ cents per pound, for real potash K_2O.

It is to be hoped that the chemical manufacturers of New England will find their advantage in employing the German muriate of potash for making muriatic acid, in place of the common salt now used for that purpose. The residual "salt cake," — a somewhat acid sulphate of soda, — that results from the present system of manufacture, is a substance that is often hard to dispose of in this region. It has very little agricultural value. But for sulphate of potash, of high grade, such as would result from the manufacture of muriatic acid from the better sorts of the German muriate of potash, there should be a well-nigh unlimited demand for agricultural purposes.

There must always be a certain advantage in transporting the muriate rather than the sulphate of potash from Stassfurt, as Professor Johnson has already remarked, because of the somewhat lower equivalent weight of the muriate. But, on the other hand, sulphate of potash is to be preferred to the muriate as a fertilizer on several accounts. The sulphate has some useful qualities of its own, and it is rather less likely than the muriate to do harm when used unintelligently.

to soluble phosphoric acid, the inherent difficulty of estimating its price has been greatly increased in this country by the lack of intelligent competition among the manufacturers, by the practice which prevails among them of mixing with their superphosphates organic nitrogenous matters of uncertain value, and by ignorance on the part of many buyers as to the real use and mode of action of the fertilizer.

Professor Johnson, of New Haven, in some of his earlier reports to the Secretary of the Connecticut State Board of Agriculture (see, for example, his reports for 1858 and for 1869), adopted Professor Stœckhardt's German estimate of 12½ cents (gold) per pound as the price of soluble phosphoric acid. But, in his report for 1870, Johnson was induced, by considerations which are discussed at some length in the report, to adopt 16¼ cents (currency), in the belief that this estimate was more just than the other. Practically Professor Johnson substituted for his former estimate (12½ cents, gold), a price that would be the equivalent of it in currency when the premium on coin was 30%. This currency price, though proposed by Johnson merely as a temporary expedient "for the present, or until more decisive data are accessible," has been accepted by so many American chemists who have had to do with the analysis of fertilizers that it may be said to have been generally adopted in this country.

But from the following considerations it will appear that at the present time (spring of 1874) 16¼ cents is much too high an estimate to put upon the pound of soluble phosphoric acid, and that even the old estimate of 12½ cents, gold, is hardly tenable.

The first item of evidence bearing upon the question has been given in a paper "On the Cost of importing Superphosphates from Europe," already published in this "Bulletin," page 170, whence it appears that soluble phosphoric acid may be imported into Boston from England at a cost of 12½ cents, per pound, currency.

The second item consists in the offers of a responsible New York dealer in fertilizers * to sell superphosphates either in New York or in Boston at prices which would make the pound of soluble phosphoric acid come at 12½ cents.†

* Mr. Geo. E. White, 160 Front Street, New York.

† The details of these offers are as follows: Mr. White will sell, in ten-ton lots, a superphosphate yielding 10% of soluble phosphoric acid at $25.00 per ton of 2000 lbs., packed at his expense, either in bags or barrels, and delivered free on board any vessel for a New England port, sailing out of New York; or he

Still further evidence, of a kind more conclusive, perhaps, to some minds than the foregoing, will be found in the following statement of a farmer's practical experience as to the cost of making superphosphate from spent bone-black and oil of vitriol, at a farm about twelve miles from Boston. The experience is that of Mr. Henry Saltonstall, Treasurer of the Massachusetts Society for Promoting Agriculture; and it is all the more valuable in its bearings upon the present aspect of the question of the valuation of soluble phosphoric acid, because the information was gained as an incidental result of actual work at the farm, that had been performed without the slightest reference to its connection with the subject now in question; in fact, without thought of formulating the results, or of paying any heed to them whatsoever.

Having learned by chance that Mr. Saltonstall had had a quantity of superphosphate made at his farm from bone-black, I wrote for a fair sample of the product, in order to get an idea of what its quality might be. Analysis showed that the sample sent by Mr. Saltonstall contained: —

Moisture expelled at 212°	34.10*	
Volatile matter (beside moisture)	16.70	
Ash left on ignition	49.20	
		100.00

The specimen contained: —

Phosphoric acid soluble in water	11.24%	
,, ,, insoluble ,,	3.15	
Total		14.39%

The large amount of moisture indicated by the analysis was no less surprising than the really excellent quality of this home-made fertilizer. In reply to my inquiries, Mr. Saltonstall wrote as follows: —

"My foreman says he dug the sample out of the middle of the pile, and that all the dampness or moisture that was ever in it had had no chance to dry off.

"To 2100 lbs. of bone-black he put 1050 lbs. sulphuric acid, and half

will deliver in Boston a soluble phosphate of lime of very high grade, — guaranteeing 37% (thirty-seven per cent) of anhydrous phosphoric acid soluble in water, — at $90.00 per ton, and *pro rata* for a higher percentage; the exceedingly concentrated form of this fertilizer enabling him to bear the cost of its transportation.

* The sample came to hand in a tightly closed bottle, and was analyzed immediately with the results given above. Another estimation of the moisture, made after the bottle with its contents had stood several weeks in a warm room, gave 32.56%.

as much again water as acid, = 1575 lbs., a total of 4725 pounds. This mixture made 3700 pounds of superphosphate, at a cost for the bone-black of $26.25, for the acid of $25, for freight from Boston, $4.50, at the outside ; for labor of making, say $5, — a total of $60.75, or say $33 per ton of 2000 pounds.

"Allowing 6 cents a pound for (3.15%) 63 lbs. insoluble phosphoric acid in a ton, the (11.24%) 225 pounds of soluble phosphoric acid cost 13 cents a pound, or ½ cent more than Mr. White asks for his two qualities in New York. So that, although I get a better article than any of the eleven superphosphates reported upon by you in No. 1 of the 'Bussey Bulletin,' both in respect to quality and cost of soluble phosphoric acid, I can in future do better probably with White, even after paying freight, because his superphosphates are presumably better made, and so less likely to 'go back,' — particularly that of the very high percentage of soluble phosphoric acid. Still, my experiment shows that buying acid at retail at 2⅜ cents per pound, and making the manure without proper knowledge or facilities, in a heap on the ground, I beat the commercial makers (except White) in quality, and expose the enormity of their profits.

"The freight and labor would both be economized in a properly regulated wholesale manufacture. My foreman mistook my orders about water. I told him 'as much water as acid.' If he had left out the extra 525 lbs. of water, the result would doubtless have been better.

"Superphosphate was made at my farm in 1873 from spent bone-black, in the same way as in 1874, except that less water was mixed with the acid; and my foreman says it was better than this year's product, that is to say, easier to handle, because less moist and pasty.

"Last year the home-made superphosphate was applied to grass with very encouraging results. Upon one part of a 6½ acre field that was laid down to grass in the spring of 1873, I used my superphosphate in connection with nitrate of soda and muriate of potash, of 82% (applied at the rate of 340 lbs., 150 lbs., and 100 lbs. per acre respectively), while another part of the field was dressed with the Manhattan Co.'s 'blood guano,' and muriate of potash, applied at the rates of 400 and 115 lbs. to the acre. No nitrate of soda was used with the blood guano, because that substance was supposed to contain in itself a sufficient amount of nitrogen.

"The grass started well upon all parts of the field, but the 2½ acres that had received the home-made superphosphate were conspicuously better than the 4 acres to which the Manhattan Co.'s blood guano was applied, until the very severe drought of last year, coming as it did in the growing months, withered up all the young grass.*

"Very truly yours, H. SALTONSTALL.

"Professor F. H. STORER, Bussey Institution."

* Mr. Saltonstall informs me that a remarkably heavy crop of grass has been obtained this year (1874) from the field in question. In order to repair

It is plain from the foregoing statement of Mr. Saltonstall's experience, that, with spent bone-black at $25 per ton, and sulphuric acid at 2⅝ cents per pound, soluble phosphoric acid may be made at any farm at a cost per pound of 13 cents (or perhaps a little less) in currency, plus, or minus, the difference between the cost of transporting the raw materials to that farm and the expense incurred by Mr. Saltonstall on this account. But the conclusion thus arrived at is almost absolutely identical with the result that was previously determined, both by the cost of importing English superphosphate, and by the prices of the New York dealer; namely, that, in appraising a superphosphate at the present time, in this part of New England, or in any part of the country equally accessible to seaports, 12½ @ 13 cents currency is the utmost that can be allowed per pound for the soluble phosphoric acid that is contained in it.

It will be noticed that Mr. Saltonstall's experience goes far to discredit a certain prejudice against the making of domestic superphosphates that has latterly been current. Chemists, in particular, have, of late years, looked with little favor upon the manufacture of superphosphates at the farm. They have argued, naturally enough, that a chemical manufacture of this kind is foreign to the farmer's legitimate business;

the damage done by the drought of 1873, the field was harrowed in August of that year, and again sown lightly with grass seed. Very early in June, 1874, the whole 6½ acres were treated with home-made superphosphate and nitrate of soda, applied at the rates of 250 and 112½ lbs. per acre. There was also applied to the 2½-acre division of the field muriate of potash (of 82%) at the rate of 100 lbs. to the acre, and to the 4-acre division sulphate of potash (of 60%), at the rate of 162½ lbs. per acre. "The abundant rains of this year have started the grass finely. Three cows and three heifers have had the run of the field, night and day, during the season, as well as of an adjoining piece of old pasture land of about 13 acres, and four horses also have been kept upon the two fields fully one-third of the time. The grass on the 2½-acre part getting so thick and high that the cattle couldn't manage it, I put in a mowing machine; left as much grass standing uncut upon the ground as I could, to cover the roots, and July 1 housed over three tons of hay from the 2½ acres which had been pastured till the grass was cut. My foreman and myself estimate that the 2½ acres were from a third to a half better than the rest of the field. If the 162½ lbs. per acre of sulphate of potash on the 4 acres in 1874 was a fair offset for the 100 lbs. of muriate per acre on the 2½ acres, then all the difference between the parts of the field that I know of came from the 1873 manuring."

"The field adjoins that on which my experiments with potatoes [see 'Bussey Bulletin,' page 137] were made. The soil is stony, with a free gravel subsoil, and very dry and leachy."

that it is something which he would not naturally undertake, and which he cannot be expected to do as well as a trained artificer. It has been shown, moreover, by analysis of home-made superphosphates, that had been prepared from raw bones, that it is by no means an easy matter to obtain high-grade products by operating on that material. There is, for that matter, good reason to doubt whether the old notion that the bones procurable at a farm should be treated with sulphuric acid can be justly commended. In the lack of facilities for reducing the bones to dust or meal, it is probably true as a general rule that they had better be decomposed by means of wood ashes or some other alkali. It is now well known that raw bones are but slowly acted upon by sulphuric acid, unless, indeed, they are finely powdered, and in that event they had probably better be applied directly to the land, as bone-dust, in most instances.

From what has been said already, it will be plain that the making of superphosphate at home, from a proper material, is really a valuable resource to the farmer. He can in this way readily protect himself not only against actual fraud, but against the excessive prices which in this country are so often demanded by the makers and vendors of superphosphates. Mr. Saltonstall's results show clearly that while the prices of the raw materials remain as they are now, the farmer has it in his power to prepare his own superphosphate, from spent bone-black,* at a cost that is not only very much lower than the prices at which superphosphates have been commonly sold in our markets hitherto, but which is really and intrinsically small, as compared with the least possible price.

It is to be remembered, moreover, that in case the supply of bone-black should prove to be inadequate to any new demand that might arise, there would still be available, for the farmer's purpose, those better kinds of phosphatic guanoes which are readily decomposed by sulphuric acid, as well as the bone-ash that is brought from South America.

* To be obtained at sugar refineries, as well as of the dealers in fertilizers.

No. 10. — *On the Average Amounts of Potash and Phosphoric Acid contained in Wood-ashes from Household Fires.* By F. H. Storer, Professor of Agricultural Chemistry.

Among the potassic fertilizers, wood-ashes will undoubtedly long maintain a prominent place, because of their very general diffusion. A manure produced at the farm or in factories, towns, or villages near the farm, must, as a matter of course, be preferred for several reasons to any competitor that has to be brought from a distance. It is evidently a matter of some importance, however, to determine, with as much precision as may be possible, just what the advantages of using the domestic product really are, and to compare it carefully with the other varieties of manure that might be used instead of it. In this view, I have thought it worth the while to have a number of different samples of wood-ashes subjected to analysis for the purpose of determining, in the first place, what are the average amounts of potash and phosphoric acid contained in ashes such as are produced in New England. If these data were once definitely fixed, the farmer would be in so far better able than he is now to contrast the money worth of ashes with that of the various Stassfurt salts and the other potassic fertilizers.

The kinds of ashes examined, and their sources, will appear from the following list. The numbers in the list correspond with those in the first column of the table of analytic results: —

Description of the Samples of Ashes.

No. I. From a barrel of "household ashes" taken from a soapboiler's store at Southbridge, Mass., in April, 1873. The soapboiler "collects his ashes from different families in and around the village, and the wood usually burned in this locality may be taken as about one half maple, one quarter white and red oak, and one quarter white pine."

II. From another barrel of household ashes, obtained from the Southbridge soapboiler, in April, 1874.

III. From a hot-air furnace in the house of Dr. George Derby, Boston. The furnace was fed with hard wood, a mixture of beech, birch, and maple, brought from St. Mary's Bay, Bear River, Cornwallis, Nova Scotia.

IV. Taken from a bin in the house of the Rev. J. Freeman Clarke, Jamaica Plain. The ashes came from a hot-air furnace and open fire-places fed with hard wood, chiefly oak, from West Dedham, Mass.

V. From open fires in the house of J. Elliot Cabot, Esq., Brookline, Mass. "The wood burnt was mostly red oak, with a little soft maple, and perhaps a very little hickory."

VI. From a hot-air furnace fed with rock-maple wood (*Acer saccharinum*), in the house of the Rev. W. O. White, Keene, N. H.

VII. From an iron stove in the house of Mr. S. S. Taylor, Dunstable, Mass. The wood burnt was maple and apple.

VIII. Beech-wood ashes from an iron stove in Monadnock Hotel, Troy, N. H.

IX. From an iron stove in house of Mr. Samuel Cunningham, Rockford, Winnebago Co., Illinois. The stove was fed with dry pin-oak (*Quercus palustris*), — the trunks of trees from four to eight inches in diameter.

X. From an iron stove in house of Mr. John Smith, Rockford, Illinois. This stove was fed with green pin-oak, from trees similar to those described in No. IX.

XI. From Louis Cabot, Esq., Manchester, Mass. The fire was fed with the trunks of old apple-trees. These ashes contained neither iron nor alumina. The sample was particularly white and clean.

XII. From Mr. F. H. Appleton's Broadfield Farm, West Peabody, Mass. Pitch-pine wood (*Pinus rigida*) burnt in an iron cooking stove.

XIII. From a farm-house fire in Ipswich, Essex Co., Mass., fed with Alder wood (*Alnus incana*).

It will be observed that none of the analyses recorded in the following table are "complete." No attempt has been made in any instance to estimate the lime, magnesia, or iron, or the sulphuric and silicic acids that are always contained in wood-ashes, or the soda and manganese that sometimes occur in them. I have confined my attention entirely to those constituents of ashes, viz., potash and phosphoric acid, that have especial interest for the farmer, because of their money value. It will be noticed, moreover, that the percentage amounts of these constituents as given below refer directly to real ashes in the condition in which they were taken from household fires, — excepting only that the lumps of charcoal were sifted out. In case any one should wish to know how much lime, magnesia, or other of the commercially speaking unimportant ingredients of wood-ashes are contained in any given sample of ashes, that information may readily be got, with sufficient accuracy for most practical purposes, from the tables of Professor Wolff (cited in Johnson's "How Crops Grow," New York, 1868, p. 379). It is to be remarked, however, that Professor Wolff's table having been constructed for another purpose, the figures differ from those given in this article, inasmuch as they do not refer to actual ashes such as are bought

and sold and applied to land, but to an ideal product obtained by subtracting from the ashes really examined certain of their so-called accidental or variable constituents ; namely, carbonic acid, sand, charcoal, and oxide of iron. Since these constituents usually amount to as much as a quarter or even a third part of the entire weight of fine sifted ashes, an allowance must be made for them upon the figures given by Wolff. For ordinary ashes (obtained from wood), a rough approximation to the truth may be made by taking $\frac{75}{100}$ (or better, $\frac{7}{10}$) of the figures in Wolff's table; or a more accurate calculation may be made by taking as the denominator of the above fraction the difference between 100 and the amount of "carbonic acid, sand, and charcoal" that has been actually found by analysts of the ashes of the particular kind of wood, bark, leaf, or fruit that happens to be in question, as given in the table on

TABLE OF ANALYTIC RESULTS.

No. of the Specimen.	In 100 parts by weight of the ashes, there were found parts of			
	Real Potash. K_2O.	Carbonic Acid. CO_2.	Sand and Charcoal.	Phosphoric Acid. P_2O_5.
I	6.23 6.46			3.16* 3.13 3.87
II	6.05			2.99*
III	10.68 10.10	25.42	5.90	1.62 1.56 1.40
IV	8.47	21.92	14.07	1.65
V	8.64	30.74	7.81	2.49 1.55
VI	8.77	28.74	1.29	2.04
VII	8.37			1.76
VIII	9.48			2.80
IX	9.04	23.42	11.91	2.20
X	7.38	20.37	5.14	0.68
XI	9.09	28.30	2.77 2.70	0.43 0.41
XII	10.83			3.75 4.58
XIII	6.77			2.27

* The comparatively large amount of phosphoric acid found in the samples marked with an asterisk is fully explained by the fact that the barrels of ashes from which these samples were taken contained numerous pieces of burnt bone. Since these bits of bone were very friable, small fragments of them undoubtedly passed through the sieve into the fine ashes taken for analysis. It is no matter for surprise that bones should thus be found in ashes that had been collected from house to house, like these that were obtained from the soapboiler; for, as is well known, in many families the stove or fire-place is the receptacle of all kinds of rubbish, especially that which is in the least degree combustible. Ashes thus charged with bone earth would, of course, be more valuable for some soils than those to which no bones have been added. The bones can readily be detected by throwing a few handfuls of the ashes upon a not too coarse sieve.

page 207. For example, Wolff's table gives the proportion of lime in birch-wood ashes as 60%. But as appears from the table on page 207, ashes from birch wood contain on the average about 28% of carbonic acid, sand, and charcoal, and consequently about 72% of ash that is free from those substances. But $\frac{72}{100}$ of $60 = 43$, or thereabouts; and this number probably represents very nearly the average amount of lime that actually exists in sifted birch ashes.

Methods of Analysis.

Care was taken in every instance to draw an average sample of the ashes from the bin or barrel that contained them. The rough sample thus taken was sifted through a sieve carrying twelve meshes to the linear inch,* and the fine powder, thoroughly mixed, was kept in a tight bottle. All the samples examined were completely dry in the ordinary acceptation of the term, but none of them were subjected to any process of drying in the laboratory, excepting the samples to be mentioned directly, in which the amount of hygroscopic moisture was estimated. The portions weighed out for analysis were purposely taken as nearly as possible in their natural condition. Except for the sifting, which was absolutely necessary to ensure a certain degree of uniformity in each sample, the ashes analyzed differed in no respect from those of every-day life. The amount of hygroscopic moisture contained in most of the samples was very small. Thus a weighed portion of No. III.

* Only a very small proportion of the original ashes was left upon the sieve in most instances. Even the mixed ashes from the soapboiler gave a comparatively small volume of coarse material. The siftings were, however, rather heavy in that case, because of the presence of nails and particles of gravel. Besides charcoal and bits of half-burnt wood, the sieve removed from the soapboiler's ashes many iron nails, fragments of glass, and pieces of bone, with here and there a broken tobacco-pipe, and a bit of crockery ware, brick, or stone.

In order to gain some idea of the amount of matter separated by the sieve, a number of two-pound samples, taken from different parts of one of the barrels of ashes obtained from the Southbridge soapboiler, were carefully sifted, and the weights of the residues left in each instance were noted. The results were as follows: Eight separate portions, of 1000 grammes each, taken from the upper third of the barrel, gave, respectively, grammes of coarse material, 125; 148; 143; 155; 149; 158; 190, and 170. (Mean of the eight trials: 154 grammes, or 15.4%.)

Five portions, of 1000 grammes each, taken from the middle part of the barrel, gave grammes of coarse material, 187; 195; 168; 188, and 166. (Mean of the five trials: 181 grammes, or 18.1%.)

Five portions, of 1000 grammes each, taken from the lower third of the barrel, gave grammes of coarse material, 201; 150; 180; 157, and 160. (Mean of the five trials: 169 grammes, or 16.9%.)

lost 0.37% of moisture on being dried at 212°, and No. IV. lost 0.51%. Sample No. I., obtained from a soapboiler's stock, gave off $2\frac{1}{2}$% of moisture.

For the estimation of *potash*, five grammes or thereabouts of the ashes were digested for half an hour or more, with concentrated nitric acid in a covered beaker. The liquor was diluted with water, thrown upon a filter, and the insoluble sand and charcoal carefully washed with hot water. The filtrate was evaporated nearly to dryness in a small porcelain dish, and thoroughly mixed with a solution of ferric nitrate. The evaporation was then pushed to dryness, and the capsule placed upon a wire tripod in a small iron pot which was heated in accordance with Deville's directions,* until the excess of nitrate of iron was completely decomposed. The residue was treated with hot water, filtered, and the filtrate and wash-water, acidulated with chlorhydric acid, were evaporated to dryness in a porcelain dish. The dry residue was drenched with strong chlorhydric acid, and the contents of the dish were again evaporated to dryness to destroy the nitric acid, this operation being repeated until no trace of chlorine could be detected, by means of iodo-starch paper, in the fumes arising from the dish. The residue, freed from nitrates, was acidulated with chlorhydric acid, and treated with as small a quantity of highly dilute chloride of barium solution as was sufficient to precipitate all the sulphuric acid, and in the filtrate from the sulphate of baryta the potassium was determined, as chloroplatinate, by Stohmann's process, as described in Fresenius's Zeitschrift für analytische Chemie, **5.** 307.†

For estimating the *phosphoric acid*, the process ordinarily employed was as follows: Five grammes or so of the ashes were digested for half an hour or more with strong chlorhydric acid in a covered beaker, and the mixture was evaporated to absolute dryness upon a water bath to render the silica insoluble. The dry residue, which contained sand and charcoal, as well as silica, was moistened with strong chlorhydric acid in the usual way, then treated with hot water, filtered, and washed. In the filtrate, phosphate of iron was thrown down by means of ammonia

* Fresenius's "Quantitative Analysis," New York edition of 1871, p. 352, § 38.

† Considerable experience with Stohmann's process enables me to say that it succeeds well in practised hands. It is of the first importance, however, that the least possible excess of chloride of barium shall be used in precipitating the sulphuric acid; for, under the conditions which obtain in an actual analysis, it may happen that the union of chloride of barium and bichloride of platinum to form the soluble chloroplatinate of barium, upon which the success of the operation depends, will be incomplete, no matter how large an excess of free chloride of platinum is present. In that event, the chloroplatinate of potassium is contaminated with crystals of hydrated chloride of barium insoluble in alcohol, which, being somewhat lighter than the true precipitate, collect upon its surface as a white, slimy powder. I have noticed that beginners almost invariably encounter this difficulty, and that it can usually be overcome by the exercise of special care in adding the chloride of barium.

in presence of acetic acid, in the usual way; and in the filtrate from the ferric phosphate, the rest of the phosphoric acid was estimated by means of a standard solution of acetate of uranium.* This process, though not absolutely accurate when employed for the analysis of products liable to contain alumina, was deemed sufficient for the purposes of this research, and has in fact approved itself to be so. It will be noticed that, besides a tendency on the part of the operator to add a little too much of the uranium salt in the process of titration, the error most likely to occur in applying this process to the analysis of wood-ashes is that due to the presence in the ashes of more or less alumina derived from earth that had adhered to the wood from which the ashes were produced. One, certainly, and probably both of these sources of error, would tend to indicate more phosphoric acid than was actually contained in the specimens of ashes under examination rather than less. The alumina would be thrown down in the form of a phosphate, together with the phosphate of iron, and would be weighed and computed as if the entire precipitate were Fe_2O_3, P_2O_5. But while a gramme of normal phosphate of iron contains 0.47 grm. of phosphoric acid, a gramme of Al_2O_3, P_2O_5, in which form the alumina is probably precipitated, contains 0.58 grm. of P_2O_5.

As will be seen directly, the amounts of phosphoric acid found in the ashes were unexpectedly small. In order therefore to make sure that the results obtained by the foregoing method were correct, other processes of analysis were resorted to. Thus, for the sake of controlling the first set of results, the phosphoric acid was estimated in samples Nos. I. and XI. by precipitating and weighing the whole of it as a highly basic phosphate of iron, after Fresenius's "Quantitative Analysis," New York edition of 1871, p. 273, and determining the amount of iron in the precipitate by titrating with permanganate of potash. These estimations were made, many weeks after those of the first set, by another analyst,† who had no knowledge as to the amounts of phosphoric acid that had been found by his predecessor, and who was moreover perfectly familiar with the iron process. There was found by the iron process 3.87% of P_2O_5 in No. I., and 0.41% in No. XI., in the samples from which the first operator, using uranium, had got 3.16% and 0.43% respectively. The agreement between these results is complete, since the soapboiler's ashes (No. I.) unquestionably contained a little alumina, all of which would necessarily be counted as phosphoric acid in the estimation by the iron process. Sample No. XI., on the other hand, contained no alumina, as has been already remarked.

* The value of the uranium solution was determined by means of pure diphosphate of soda that had been dried at 100° C. Phosphate of soda thus dried is a compound of perfectly constant composition ($2\ Na_2O$, H_2O, P_2O_5), that can be weighed without the least trouble, or risk of alteration.

† My assistant, Mr. W. T. Leman. For the first set of determinations, and for most of the other analytical work, I am indebted to my assistant, Mr. James A. Beatley.

In sample No. III. the second analyst, Mr. Leman, estimated the phosphoric acid by precipitating with molybdate of ammonia,* from a nitric acid solution of the ashes, after silica, sand, and charcoal had been eliminated. Ignorant, as before, of the result (1.62%) previously obtained, he found 1.56% of phosphoric acid. This evidence was conclusive as to the general accuracy of the uranium process. Still it was not impossible that a part of the phosphoric acid in the ashes might be in the condition of some other modification than the ordinary tribasic variety, in which event a part of it would not be precipitated by the reagents employed in the processes that have been described thus far. Several qualitative trials, made with different samples of ashes, and by various processes to test this idea, gave no reactions other than those of the tribasic phosphate. A quantitative estimation of the phosphoric acid in sample No. III. was made also after the material had been subjected to treatment which should convert any pyro- or meta-phosphate the ashes might contain into the ordinary phosphate. The silica, sand, and charcoal having been separated in the manner above described, the dry residue obtained on evaporating the filtrate was fused with a mixture of carbonate of soda and chlorate of potash, † and the phosphoric acid, estimated as usual by means of a standard uranium solution, after separation and collection of the phosphate of iron. There was found 1.40% of phosphoric acid, or rather less than before.

Finally, samples Nos. V. and XII., in which exceptionally large amounts of phosphoric acid had been indicated by the usual uranium process, were precipitated anew by means of molybdate of ammonia, after the silica, sand, and charcoal had been separated, and the dried residue of the filtrate therefrom had been fused with carbonate of soda and chlorate of potash. There was found in No. V. 1.55% of phosphoric acid; *i.e.*, decidedly less than by the uranium process, and in No. XII. 4.58% or almost one per cent more than had been indicated by the uranium method. As regards No. XII. the discrepancy is doubtless due to the circumstance that this particular sample of ashes was so little homogeneous that the portions of material taken for analysis by the different operators could hardly have been of like composition. In point of fact the pitch-pine ashes were highly charged with silicious sand in grains of the most diverse sizes. The peculiarly coarse, rough bark of the pitch-pine is well adapted to catch and hold considerable quantities of sand and earth, even when the trees are standing. The large amount of phosphoric acid found in No. XII. may be due either to the large proportion of bark which belongs to pitch-pine wood, and which is probably richer in phosphoric acid than the wood, or possibly to the burning of pine cones in conjunction with the wood. Perhaps the peculiar manner in which the wood in question

* After Fresenius's "Quantitative Analysis," New York edition of 1871, p. 271.

† After Gilbert, Fresenius's "Zeitschrift für analytische Chemie," 1873, **12.** 3.

burns may have had some influence upon the amount of phosphoric acid in the ashes. As is well known, the combustion of pitch-pine wood is difficult after the first flaming due to the distillation of the resinous matters that is contained in the wood. The wood itself smoulders away slowly without evolving much heat. The ashes numbered V. contained a noteworthy amount of manganese, which undoubtedly vitiated the results obtained by the uranium process. It was noticed from the first that this sample of ashes evolved chlorine on being heated with chlorhydric acid, and that during the fusion with chlorate of potash a very considerable quantity of manganese oxide separated out.

The *carbonic acid* set free from 3 or 4 grms. of the ashes, by means of diluted chlorhydric acid, was collected in potash bulbs and soda-lime tubes, and weighed, as such, after Kolbe.* To estimate the *sand and charcoal* 5 grm. samples of the ashes were treated with a cold mixture of equal volumes of concentrated chlorhydric acid and water, and the mixture was filtered rapidly as soon as the action of the acid upon the ashes seemed to have ceased.

The average amount of potash (about 8½ per cent) found in the foregoing samples of wood-ashes from domestic fires, agrees tolerably well on the whole with the results of previous analysts, and with the practical experience of potash-makers, though it is rather less than might perhaps have been expected from a comparison of the best analyses that have been carried out hitherto from the purely scientific point of view.†

But with regard to phosphoric acid there are noteworthy differences between the results recorded in the table above and those that have been obtained previously by chemists. With a single exception, decidedly less phosphoric acid has been found in the samples of household ashes examined in this laboratory than has hitherto been supposed to exist in wood-ashes. I have searched with some care for published determinations that should corroborate those given above, but have found very few such.‡ Some of the results of this search

* Fresenius's "Quantitative Analysis," p. 294.

† Compare the table on page 207.

‡ The few analyses of commercial ashes that have been published hitherto agree tolerably well with my own results. Thus Heiden, in his "Düngerlehre," **2.**231, reports that a sample of fir ashes, bought and analyzed by him, contained 3.15% of potash, 20.72% of carbonic acid, 31.24% of sand and charcoal, and 2.42% of phosphoric acid. Th. Dietrich (Hoffmann's "Jahresbericht," 1867, **10.**207) found 5.6% of potash and 3.1% of phosphoric acid in a sample taken from a large quantity of ashes, mostly from beech-wood, that had been bought up from house to house; and Wicke (Hoffmann's "Jahresbericht," as just

are given in the table on page 207. A glance at the figures of that table will show how small the average proportion of phosphoric acid in the New-England ashes really is, see page 193, as compared with what we have hitherto had reason to believe.

From the statement of the actual analytical work that has been given already, it will be seen that pains were taken to control the estimations of phosphoric acid in such manner that the fact of the small proportion of this substance in household ashes should be established beyond all chance of doubt. On the other hand, I have satisfied myself by a critical examination of many of the analyses reported by previous observers that their results also are generally correct. There is no occasion to doubt that carefully prepared samples of wood-ashes really contain as much phosphoric acid as the published analyses have indicated.

The reason why there is less phosphoric acid in ashes obtained from domestic fires than in ashes that have been made on purpose for analysis, doubtless depends upon the circumstance that the household ashes have not been "carefully prepared." It is plain that when wood is burnt in an ordinary stove or fireplace, for the sake of evolving heat, some part of the phosphorus compounds in the wood must inevitably be exposed to conditions that are unfavorable for the retention of phosphates in the ashes. There can hardly fail to be conditions in some parts of the fire that are favorable for the destruction of phosphates, either by simple removal of oxygen by hot carbon or carbonic oxide, as in that process of making phosphorus where an acid phosphate is heated with charcoal, or by the combined action of silica and carbon, as in Wœhler's method of preparing phosphorus.

It was pointed out long ago by John * that the phosphates contained in plants might be partially decomposed by the action of carbon in the preparation of ashes. At a later period, Erdmann † was at pains to

cited) found 6.55% potash, 2.84% phosphoric acid, 18.79% carbonic acid, and 34.80% of sand, clay, and charcoal in the fine part of a sample of commercial ashes that seemed to him to be very impure. The original ashes from which those analyzed by Wicke were sifted left 34.85% of charcoal and other coarse materials upon the sieve. These three samples were from different parts of Germany.

* In his "Ernährung der Pflanzen," Berlin, 1819, pp. 152, 153.

† "Annalen Chemie und Pharmacie," 1845, **54.** 353; further "Journal für praktische Chemie," **31.** 17 and **39.** 276.

show that, in preparing ashes for analysis, some phosphorus will be lost, by way of volatilization, unless an abundant supply of air is kept constantly in contact with the carbonized vegetable matter, when it comes to be ignited. The risk of losing phosphorus in this way has been admitted, and dwelt upon by H. Rose, Strecker, Wolff, and other chemists who have had to do with ash analysis. Rose,* in particular, has shown, by direct experiment, that much phosphoric acid may be lost, by way of volatilization, when charcoal that contains an alkaline phosphate is calcined.

Schlœsing † has even gone so far as to base a method for the quantitative estimation of phosphorus upon the fact that the whole of this substance can be expelled from phosphate of lime, phosphate of magnesia, and the allied phosphates, by heating an intimate mixture of the phosphate and silica white-hot in a current of carbonic oxide.

Braconnot ‡ noticed, further, that soot from wood fires contains an appreciable quantity of phosphoric acid. In a sample of soft, pulverulent soot, taken from the middle of a chimney, he found nearly three-quarters of one per cent of phosphoric acid.

As a matter of fact, when reducing wood or any other vegetable matter to ashes, with the view of analyzing the latter, chemists have long recognized the necessity of operating upon small quantities of the material at comparatively low temperatures, and under such conditions that there shall be free access of air, in order to avoid, in so far as may be practicable, the reducing action of the organic matter. It is not impossible, for that matter, that some phosphorus may be lost in combination with hydrogen during the process of distillation, to which, in every fire, some part of the fuel is necessarily exposed.§

Besides the waste, by way of volatilization, a certain amount of phosphorus is undoubtedly lost in the form of a compound, insoluble in acids, that remains with the "sand and charcoal," in an ordinary analysis. I find that phosphoric acid can readily be detected in the mixtures of sand and charcoal from household ashes that have resisted the action of strong chlorhydric acid. This observation is in accord with the experience of H.

* Poggendorff's "Annalen," 1850, **79.** pp. 421, 422. Compare *ibid.*, **76.** 334.

† Liebig & Kopp's "Jahresbericht," 1864, **17.** 692, from "Comptes Rendus," **59.** 384.

‡ "Annales de Chimie et de Physique," 1826, **31.** 87.

§ Compare Violette, "Annales de Chimie et de Physique," 1851, **32.** 332.

Rose,* who proved by numerous experiments that charcoal, prepared even at low temperatures, from vegetable and animal matters, rich in phosphorus, always retains a certain amount of a phosphorus compound that is insoluble in acids. We are ignorant as to the precise character of the insoluble compound or compounds thus left with the charcoal. None of them have ever been isolated. But in the case of wood-ashes, such as have here been examined, there are grounds for believing that a part at least of the insoluble matter may be phosphide of iron, or some other metallic phosphide.

There are many instances on record of the ease with which phosphates are reduced to phosphides under conditions such as are probably to be found in some parts of almost every domestic fire where the ashes are strongly heated in contact with the particles of carbon with which they are admixed, or in an atmosphere of carbonic oxide or of carburetted hydrogen. One of the commonest methods employed by chemists for preparing metallic phosphides, is to ignite a quantity of the metal or of its oxide with a mixture of bone-black, quartz-sand, and charcoal, either with or without an alkaline flux. † Phosphide of iron, in particular, may be readily prepared, after Berzelius, by igniting a mixture of phosphate of iron and lamp-black, or some other form of carbon. It is a fact well known to metallurgists, that iron and phosphorus combine with one another with special ease to form a very stable phosphide. When iron-ores that are contaminated with phosphates are smelted, all, or nearly all, the phosphorus that was contained in them, as well as that contained in the fuel, is found in the iron, in the form of a phosphide.‡

I have myself noticed that very considerable amounts of impure phosphide of iron may be produced by igniting in a platinum crucible the mixed precipitate of basic acetate and phosphate of iron, that is obtained in the ordinary analytical process of precipitating phosphoric acid by means of a ferric salt in presence of free acetic acid. In employing this method of analysis, it is in fact an essential requisite to success that the mixed precipitate of ferric phosphate and acetate shall not be ignited directly. The precipitate must be dissolved in acid, after it has been washed, and be reprecipitated as simple phosphate before it can be ignited and weighed. In case phosphide of iron has once been formed within the mass by igniting it in contact with the ferric acetate, it is idle to attempt to oxidize the phosphide, either by long-continued ignition of the precipitate in the air, or by repeatedly drenching it with nitric acid. The inertness and persistence of the impure phosphide of iron formed under these conditions are remarkable. It resists the action of strong acids, like the phosphide de-

* Poggendorff's "Annalen," 1847, **70.** 449; 1849, **76.** 305; 1850. **79.** 398; **80.** 94.

† Compare Berthier, "Traité des Essais par la Voie Sèche," **1.** 567, and Gmelin's "Handbook of Chemistry," **5.** 222.

‡ Compare Wagner's "Jahresbericht," **6.** 32 and **9.** 40.

scribed by Berzelius. It does not decompose on being heated either with nitric acid, with nitrate of iron, or with nitrate of ammonia. On fusing it with bisulphate of soda or bisulphate of potash, it seems to be scarcely at all acted upon at first. Only after repeated fusions with the bisulphate does it wholly disappear. When fused repeatedly with fresh portions of a mixture of borax and carbonate of soda it can be destroyed somewhat more rapidly, especially if the residue left by each fusion be heated with strong chlorhydric acid. It is not strange that the discoverers of the phosphide mistook it for a new metal.

It is to be remarked in this connection that Schlœsing found his process of analysis, described above on page 200, inapplicable to phosphate of iron. From that substance he could not expel the phosphorus by his process of heating with carbonic oxide and silica.

It is safe to assume that any phosphide of iron that may occur in wood-ashes will be wholly devoid of agricultural value.

Whatever the explanation of the fact may be, the loss of phosphoric acid from vegetable matter that is burnt to ashes is a point of some significance for the practical farmer. Not only does it appear from the analyses here recorded, that wood-ashes are in general of somewhat less consequence as a phosphatic manure than had been supposed hitherto; but a new objection to the use of fire in agriculture may henceforth be urged. It is now plainer than ever that the processes of fermentation and decay that occur in the compost heap are better agents than fire for the reduction of coarse vegetable matter to the condition of manure. When weeds, clods, chips, and brushwood are composted, it is not only their nitrogen that is saved and put to use, but the whole of the phosphates and other inorganic matters that are contained in them.

Note on the Phosphoric Acid in Leached Ashes.

It is to be remarked, with regard to the small proportion of phosphoric acid in wood-ashes, that the results obtained by Professor Johnson,* of New Haven, in his recent examination of leached ashes, such as are obtainable in New England, go to corroborate those recorded above. Johnson analyzed four samples of leached ashes; viz., No. I. a sample taken by himself from a large heap of leached ashes at an "ashery" at Deer River, Lewiston, New York. Nos. II. and III. from separate cargoes of leached ashes brought from Canada, the first in 1863, and the last in 1873, and No. IV. from a soapboiler's in New Haven; this last had been adulterated with coal-ashes.

* "New York Druggists' Circular," Dec. 1873, p. 202; from a "Report to the Connecticut State Board of Agriculture."

Assuming, for the sake of comparison, that all the samples contained 35 per cent of water, which was the amount found in those from the Canadian cargo No. III., the results of the analyses may be stated as follows: —

	I.	II.	III.	IV.
Potash	0.8	2.3	0.7	0.9
Soda	0.2	none	none	
Lime	29.7	28.1	23.2	21.3
Magnesia	3.4	3.3	2.9	4.1
Oxides of iron, manganese, and aluminum	0.8	1.7	1.5	2.7
Phosphoric acid	1.3	1.3	1.4	1.1
Sulphuric acid	none	0.2	0.1	0.1
Silica, soluble in alkali	2.6	2.3	2.8	3.9
Carbonic acid	19.9	18.2	17.1	20.2
Coal	0.8	3.3	5.0	26.8
Sand and soil	5.5	4.3	10.3	
Water	35.0	35.0	35.0	35.0
	100.0	100.0	100.0	100.0
Carbonate of lime	53.	50.	42.	38.

These results accord very nearly with an analysis made twenty years ago by Otto Stein,* of leached ashes from a soapboiler's at Heilbronn in Germany. These leached ashes were largely used as a manure by the peasants of the Odenwald, and were highly esteemed by them. The sample analyzed was taken from a large store of the material which was of dark-gray color and in part soft and sticky, while the rest was drier and admixed with fragments of lime and charcoal.

The sample, dried at 212° F., contained: —

Matters soluble in boiling water ... 1.94 =	Potash	0.06
	Soda	0.65
	Chloride of Sodium	0.15
	Carbonates of Alkaline earths	0.72
	Silica and organic matters	0.36
Matters soluble in chlorhydric acid ... 69.73 =	Potash	0.19
	Soda	0.28
	Sulphuric acid	0.46
	Phosphoric acid	1.14
	Oxide of iron	2.19
	Alumina	3.08
	Lime	29.51
	Magnesia	5.66
	Carbonic acid	22.67
	Carbon	4.57

* "Journal für praktische Chemie," 1854, **63.** 51.

Matters insoluble in
chlorhydric acid = 29.00

100.68

Or altogether: —

Potash } together 1.17 {	0.24
Soda	0.93
Chloride of sodium	0.15
Lime	29.51
Magnesia	5.66
Carbonates of lime and magnesia dissolved by water	0.72
Oxide of iron	2.19
Alumina	3.08
Phosphoric acid	1.14
Sulphuric acid	0.46
Silica and organic matter dissolved by water	0.36
Carbonic acid	22.67
Carbon	4.57
Matters insoluble in acid	29.00
	100.68

It is plain from my own results, as well as from those of Professor Johnson and of Stein, that the fertilizing action even of leached ashes cannot any longer be specially attributed to the phosphates that are contained in them. No doubt the small proportion of phosphates actually present is useful, so far as it goes, but so is the potash also; and in a fertilizer so poor as leached ashes are, in respect to the more important elements of plant-food, the lime and magnesia compounds undoubtedly have considerable significance.

The idea which has been accepted and promulgated by many writers upon agricultural chemistry, that leached ashes are rich in phosphates, appears to have been based upon some of Berthier's * analyses of the insoluble part of several kinds of wood-ashes that had been carefully prepared by him in the laboratory, and upon the general inference, drawn from numerous other analyses of laboratory products, such as are reported in the table on page 207, that, if fresh ashes contain 5% or so of phosphoric acid, the insoluble matter in those ashes which usually amounts to some 85 or 90 parts, and in which almost the whole of the phosphoric acid would naturally be retained, must be credited with as much as 5½ or 6% of it. Certain rough analyses of leached ashes, such as are used as manure in the south of France,

* "Annales de Chimie et de Physique," 1826, **32.** 248.

made long ago by Bobierre,* and often quoted, seemed to fully accord with the above view, and to give it direct support. Bobierre's analyses indicate as much as 11 or 12, and in one instance even 27 per cent of "phosphate of lime mixed with alumina and oxide of iron." It is manifest, however, that statements so little precise as these are wholly insufficient to prove that leached ashes are to be regarded as a phosphatic manure. Bobierre himself has in fact repeatedly urged that leached ashes, such as those examined by him, are very often largely adulterated with earth that is rich in alumina and oxide of iron.

An analysis of soapboilers' leached ashes by Emil Wolff, given in his "Naturgesetzlichen Grundlagen des Ackerbaues," Leipzig, 1856, p. 466, which has served not a little to support the inference that phosphoric acid is a prominent constituent of leached ashes, is really not precise enough to lend any strength to that idea. Wolff's statement of results reads as follows: —

Carbonate of lime	41.55
Phosphate of lime, together with some alumina and oxide of iron	11.30
Soluble silica	3.25
Magnesia	2.55
Potash	0.74
Sand and clay	36.16
Organic matter	4.61
	100.16

It is possible of course that the ashes analyzed by Wolff were exceptionally rich in phosphates, or it may be that they contained fragments of bone, so that there was really as much as 10 or 11% of phosphate of lime found in them (*i.e.* from 4½ to 5% of phosphoric acid), but it is much more probable that the iron and alumina above reported constituted a very considerable proportion of the 11.3% of material that is set against their names. It will be noticed that the German leached ashes examined by Stein (page 203) contained some 5% of alumina and oxide of iron.

From what has been shown thus far, it seems plain that a little less than 2% of phosphoric acid is all that can be allowed in computing the average value of dry ashes, whether fresh or leached.† While for

* Pierre's "Chimie Agricole," Paris, p. 562 of the first edition.

† That is to say, with addition of lime, as is the general practice in this country, and the custom of soapboilers everywhere. It will be noted that the 6 or 8 per cent of lime added to the fresh ashes before leaching goes far to sup-

the leached ashes of commerce, charged with more than a third their weight of moisture, no more than $1\frac{1}{3}\%$ of phosphoric acid can be allowed on the average, as appears from Johnson's figures on page 203.

The following table, to which frequent allusion has been made in the preceding pages, has been compiled from the published statements of various chemists who have analyzed the ashes of woody plants. As has been already indicated most of the estimations of potash and phosphoric acid were made in ashes that had been prepared expressly for analysis. A more complete table than the one here given could undoubtedly be constructed, at the cost of considerable time and trouble. It is believed, however, that this one will be sufficient to give a just idea of what has been done hitherto by chemists in this department of ash analysis, and to illustrate the allusions to such work that have been made in the text.*

The column relating to "salts soluble in water, or crude potashes," has been given partly for the sake of future reference, and partly because the figures contained in it, may, in the lack of more precise indications, serve to indicate approximately the amount of real potash that the sample in question contained. For in case the matter reported as "salts soluble in water, or crude potashes," were all carbonate of potash, as by far the larger part of it actually is in most instances, the amount of real potash could at once be calculated, since in every 100 parts of carbonate of potash there are 68 parts of real potash. A rough approximation to the amount of potash in any sample of ashes may therefore be had by taking $\frac{6}{10}$ or $\frac{7}{10}$ of the figures given in the column relating to salts soluble in water.

ply the weight of the soluble matters that are removed by water, so that the proportion of phosphoric acid in the dry leached product may be very nearly the same as it was in the fresh ash.

* It will be noticed that the figures in the table all refer to quantities of wood and of ashes that have been weighed, not measured. But since both wood and ashes are commonly bought and sold by measure in this country, it may be well to remark that a bushel of household ashes is said to weigh about 48 pounds on the average. With regard to the weight of different kinds of woods, it appears from the experiments of Bull ("Transactions of the American Philosophical Society," Philadelphia, 1830, **3.** 60), that there are about 1800 lbs. of dry wood in a cord of white pine, 1900 lbs. in a cord of pitch pine, about 3300 lbs. in a cord of the ordinary oaks, 3800 lbs. in a cord of white oak, and as much as 4500 lbs. in a cord of shell-bark hickory. Not to repeat Bull's copious table, it may be said in general terms, that he usually found about 2500 or 3000 lbs. of dry wood to the cord.

TABLE OF THE PERCENTAGE OF ASHES IN VARIOUS KINDS OF TREES AND WOODY PLANTS, AND OF THE AMOUNTS OF PHOSPHORIC ACID AND POTASH THAT HAVE BEEN FOUND IN SUCH ASHES.

Name of the tree or shrub.	Part of the plant examined. The terms "wood" and "body-wood" usually mean large wood *with its bark*, such as is ordinarily used for fuel.	Time when the plant was gathered.	Condition of dryness when examined. When no particulars are given the wood was probably air dried.	Per cent of ash found.	In 100 parts, by weight, of the ashes there were found, among other things, parts of: Salts soluble in water, *i.e.*, crude potashes.	Real Potash. K_2O.	Carbonic acid, sand, and charcoal.	Phosphoric Acid. P_2O_5.	Observer. For particulars, see the numbered list of names at the end of the table.
ACACIA. See Locust.									
ALDER, common of Europe (*Alnus glutinosa*)	Wood			1.39					1. v. Werneck.
	do.		Dry	1.38	(mean of 26 experiments)				30. Chevandier.
	do.		Dry	1.11					20. Brix.
	do.		Fresh	0.95					
	do.			2.54	15.46				10. Leuchs.
	do.				16.80				59. Uhden.
	do.				15.72				19. Simon.
	do.		Dry	2.51	14.68				52. Leipzig œk. Gess.
	Copse-wood				18.80		?	4.74	4. Berthier.
	do.					62 % of the soluble salts	?	9.22 % of the insoluble part of the ashes	4. Berthier, Voie sèche, p. 264.
	Heart-wood, free from sap-wood, from tree 40 to 50 years old		Dry	0.32					5. Sprengel.
	Branches and leaves				14.92				19. Simon
	Leaves & tips of twigs	29 July	Dried at 100°	4 13					61. Stoeckhardt.
	Leaves	Summer	Air dried	5.31					Dietrich, cited by (2) Henneberg, 1862, Supp. p. 85
	do.	August	Air dried	6.11					60. Sprengel.
	Roots		Dry	1.86	12.41				52. Leipzig œk. Gess.
	do.			1.40	7.14				40. Hohenstein.
	Fruit	Dec.	Air dried	1.71		22.02	23.58	10.69	Röthe, Bericht d. Naturhistorischen Vereins in Augsburg, 1857, **10.** 40.
ALDER, hoary-leaved of Europe (*Alnus incana*)	Wood	June	Air dried	0.61		22.19	21.30	10.69	7. Johnson and Sendtner.
	Leaves & tips of twigs	29 July	Dried at 100°	4.50					61. Stoeckhardt.
	Fruit	Jan.	Air dried	1.94		33.68	22.03	7.66	8. Röthe.
	Ditto, from another locality	do.	do.	2.58		25.98	20.42	13.00	

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	
ALMOND (*Amygdalus communis*)	Sweet kernels of fruit without shells		Dried at 100°	4.90		27.95	00.00	43.63	9. Zedeler.
	Oil cake from do.		Air dried of commerce	5.63 3.15 4 60 3.88					E. Schulze. Hilger. Nessler & Fellenberg Hoffmann's Jahresbericht 1870-71, 3. 20.
ANACAHUITE Wood (*Cordia Boissiera*)	Wood free from bark		Dry	1.81		1.09 ?	?	Traces.	Ziurek, cited in Amer. Journ. Pharm., 33. 321.
	Wood Parenchyma		Dry Dry	2.93 20.00					Buchner, cited in Amer. Journ. Pharm , 33. 322. See Ibid., 35. 86.
APPLE (*Pyrus malus*)	Wood					19.24	00.00	4.90	Engelmann, cited by Liebig, p. [404.
	Branches, 1 to 2 c.m. thick, with their bark	Oct.			9.44	10.12	00.00	3.20	13. Malaguti and Durocher.
	Wood				10.00		36.30	3.80	3. Gueymard.
	Bough on which mistletoe was growing			1.29		13.67	26.21	3.93	14. Fresenius and Will.
	Bough on which mistletoe was growing	June.				3.46	26.97	4.01	15. C. Erdmann.
	Entire fruit		Fresh	0.46 0.26 0.38					11. Margold.
	Entire fruit		Fresh	0.27		29.21	14.89	11.24	17. Richardson.
	Entire fruit		Fresh	0.28 0.39 0.47					18. Fresenius's pupils.
APPLE, Chinese (*Pyrus spectabilis*)	Stem Leaves Fruit				4.00 7.00 33.10				49. Vogel.
APRICOT (*Prunus armeniaca*)	Wood				10.70		38.41	3.85	3. Gueymard.
	Fruit		Fresh	0.50					11. Margold.
	Entire fruit		Fresh	0.89 0.86 0.78					18. Fresenius's pupils.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
ASH, common of Europe (*Fraxinus excelsior*)	Body-wood		Dry	1.91	11.81				52. Leipzig œk. Gess.
	do.			2.30	12.32				1. v. Werneck.
	do.			2.25	11.11				40. Hohenstein.
	do.				6.07				19. Simon.
	Heart-wood, without sap-wood, from a tree 40 to 50 years old		Air dried	0.55					5. Sprengel.
	Roots			1.56	14.76				52. Leipzig œk. Gess.
	Leaves & tips of twigs	29 July	Dried at 100°	9.15					61. Stœckhardt.
	Leaves	August	Air dried	6.23					60. Sprengel.
ASPEN. See Poplar.									
Atherosperma moschatum	Bark		Dried at 100°	4.05		4.04	30.01	1.19	21. Zeyer.
BARBERRY (*Berberis vulgaris*)	Stems ?			0.80	12.50				40. Hohenstein.
BAYBERRY (*Myrica cerifera*)	Bark of root		Air dried	12.50					22. Hambright.
BEAM TREE. See under Pear.									
BEECH, common of Europe (*Fagus sylvatica*)	Body-wood			1.26	16.09	10.72			Wiegleb, cited by (25) John, pp. 23-24.
	do.			1.34	13.90				
	do.			1.30 1.11					Baer, in Brix's Heitzkraft.
	do.			2.20	9.10–18.20				Grabner, cited by (40) Hohenstein.
	do.			1.60	8.75				Pfeil, cited by (40) Hohenstein.
	do.			0.56	21.90				27. Kirwan.
	do.		Dry	0.59	24.76				53. Régie.
	do.			0.61	21.24				1. v. Werneck.
	do.				20.23 22.28 23.81				v. Werneck, cited by (25) John, p. 159.
	Body-wood of old trees		Fresh Dry	1.43 1.84					20. Brix.
	do. of young trees		Fresh Dry	1.39 1.62					
	Wood			0.60	20.00				10. Cited by Leuchs.
	do.		Dry	1.77	10.53				52. Leipzig œk. Gess.
	do.				18.20				59. Uhden.
	do.			1.65	10.30				10. Cited by Leuchs.

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
BEECH — *continued*	Wood	. . . .	Dry	1 06 (mean	of 93 expts.	. . . .	. . . .	. . . .	30. Chevandier.
	do. tree 70 years old	. . . .	Dried 140° (c.)	0.86	. . . .	. . . .	. . . .	. . . .	
	do. tree 69 years old	. . . .	Dried 140° (c.)	0.88	. . . .	. . . .	. . . .	. . . .	31. Chevandier.
	do. tree 58 years old	. . . .	Dried 140° (c.)	1.00	. . . .	. . . .	. . . .	. . . .	
	Body-wood	. . . .	. . . .	0.39	. . . .	. . . .	. . . .	. . . .	33. Wunder.
	do.	. . . .	Dried at 100°	0.38	27.77	9.85	?	Not a large amount	34 Hertwig.
	do.	. . . .	. . . .	. . . .	16.00	10.26 *	31.18	4.18	Berthier, Annales de Chimie et Physique, 1835, **59.** 252.
	do.	. . . .	. . . .	. . . .	23.90	. . . .	. . . .	3.88	4. Berthier.
	do. with its bark	. . . .	. . . .	. . . .	. . . .	13.17	19.60	6.05	35. Heyer.
	Body-wood	. . . .	. . . .	. . . .	. . . .	11.80	25.63	2.29	36. Böttinger.
	do.	. . . .	. . . .	. . . .	. . . .	10.91	39.03	5.64	37. Witting.
	do. from another locality	. . . .	. . . .	. . . .	. . . .	6.94	31.95	7.54	
	Wood, tree 40 years old, with bark	. . . .	Dried at 100°	0.66	. . . .	. . . .	. . . .	. . . .	
	Ditto, without bark	. . . .	Dried at 100°	0.44	. . . .	. . . .	. . . .	5.74 †	
	Middle of stem, with bark	. . . .	Dried at 100°	0.68	. . . .	. . . .	. . . .	. . . .	32. Handtke.
	Ditto, without bark	. . . .	Dried at 100°	0.45	. . . .	. . . .	. . . .	7.07 †	
	Top of stem, with its bark	. . . .	Dried at 100°	0.88	. . . .	. . . .	. . . .	. . . .	
	Ditto, without bark	. . . .	Dried at 100°	0 58	. . . .	. . . .	. . . .	13.43 †	
	Heart-wood, from tree 40-50 years old, without sap-wood	. . . .	Air dried	0.37	. . . .	. . . .	. . . .	. . . .	5. Sprengel.
	Cord-wood, 1st quality	. . . .	Dry	1.24	. . . .	. . . .	. . . .	. . . .	Baer, Jahresbericht, **1.** 1112.
	Cord-wood, 2d quality	. . . .	Dry	0.57	. . . .	. . . .	. . . .	. . . .	
	Body-wood	. . . .	Dried at 100°	0.74	. . . .	12.19	33.86	3.04	38. Wittstein.
	Wood from branches	. . . .	Dried at 140°	2 15	. . . .	. . . .	. . . .	. . . .	31. Chevandier.
	Small branches	May	Dry	2.36	. . . .	. . . .	. . . .	. . . .	54. Pertuis.
	Small wood with bark	. . . .	. . . .	. . . .	. . . .	12.52	17.41	9.61	35. Heyer.
	Twigs without leaves	. . . .	. . . .	. . . .	. . . .	11.81	16.31	10.29	35. Heyer.
	Wood from twigs	. . . .	Dried at 140°	1.29	. . . .	. . . .	. . . .	. . . .	31. Chevandier.
	Fagots of young twigs from tree 25-30 yrs. old	. . . .	Dried at 140°	1.50	. . . .	. . . .	. . . .	. . . .	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* K_2O and Na_2O.

† Mean of entire year.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
BEECH — *continued*	Fagots of branches from tree 70–80 years old		Dried at 140°	1.71-1.94					31. Chevandier.
	Fagots of branches from tree of 120 years		Dried at 140°	1.93					31. Chevandier.
	Tips of twigs & leaves	August		4.94		17.80	14.49	6.71	C. Fresenius, Versuchs-Stationen, **1.** 90.
	Buds collected at moment when they had begun to develop		Dry	4.22					54. Pertuis.
	Leaves	August	Air dried	6 92					60. Sprengel.
	Leaves & tips of twigs	29 July	Dried at 100°	4.18					61. Stoeckhardt.
	Leaves of a 65 year old tree	Autumn	Dried at 100°	7.12		7 47	22.24	5.24	39. Krutsch.
	Leaves	do.				5.10	10.55	4 82	35. Heyer.
	do.		Dried at 100°	4.30		17.80	13.41	10.39	38. Wittstein.
	Leaves, rakings	Autumn	Dried		0.44				52. Leipzig œk. Gess.
	Leaves, withered of	do.		6.58		1.96	00.00	1.18	28. Wicke.
	Leaves, fallen of	do.	Dry	5.60	8.50		?	5.09	12. Gueymard.
	Leaves, autumn-ripe, raked from beneath the trees	Nov.	Air dried	6.70					60. Sprengel.
	Leaves of a 20 to 30 year old tree	Late autumn, dead on tree	Air dried	7.67					
	do.	do.	Dried at 100°	8.70		0.99	25.35	1.95	41. Zöller.
	do.	Nov.	Air dried	8.48		4.23	23.54	2.90	41. Zöller.
	do.	16 May	Air dried	5.41		29 96	28.75	24.21	41. Zöller.
	do.	18 July	Air dried	7.57		10.72	37.51	5.18	41. Zöller.
	do.	15 Oct.	Air dried	10.15		4.85	32.20	3.48	41. Zöller.
	Leaves	7 May	Dried at 100°	4.67		31.23	?	21.27	Rissmüller, Landswirthschaftliche Versuchs-Stationen, 1874, **17.**, pp. 21-30.
	do.	11 June.	Dried at 100°	5.20		21.74	?	8.43	Rissmüller
	do.	14 July	Dried at 100°	7.45		11 85	?	5 24	Rissmüller
	do.	11 Aug	Dried at 100°	9.03		9 81	?	4.53	Rissmüller
	do.	11 Sept.	Dried at 100°	8.90		10.53	?	4.24	Rissmüller
	do.	27 Oct.	Dried at 100°	10.80		7.67	?	3.22	Rissmüller
	do.	18 Nov.	Dried at 100°	11.42		5.78	?	1.08	Rissmüller
	Bark of old stem		Air dried	4.45		14.72	00.00	0.36	28. Wicke.
	Bark			7.09					42. Schulze.
	do.		Dried at 100°	6.62	3.02			More than in the wood	34. Hertwig.
	Roots		Dry	1 67	3.00				52. Leipzig œk. Gess.
	Nut-cake		Dried at 100°	5.15		13.98	6.69	20.93	Karmrodt, cited by (2) Henneberg, 1862, Supp. p. 89.
	Nut-cake, from unshelled nuts			4.25					Kreusler, Hoffmann's Jahresbericht, 1870-72, **3.**, p. 19.

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
BEECH — *continued*	Bark from lower trunk of a tree 40 years old		Dried at 100°	3.90				3.80 *	32. Handtke.
	Bark, middle of tree		Dried at 100°	3 26				4.68 *	
	Bark, top of the tree		Dried at 100°	2.98				5.58 *	
	Nuts					18.13	18.50	16.53	43. Souchay.
	Kernels of nuts		Dried at 110°	3.75		16.70	2.42	29.72	44. Brandl and Rakowiecki.
	Husks of nuts		Dried at 110°	2.20		0.85	35.50	1.40	
BILBERRY (*Vaccinium myrtillus*	Entire plant above roots	May or June	Dry	3.44		28.10	00.00	9.60	Weinhold, Versuch-Stationen, [1864, **6.** 50.
	do.	29 Aug.	Dried at 25°	2.60	17.00				45. De Saussure.
	Ditto, from another locality	20 Aug.	Dried at 25°	2.20	24.00				
	do.				23.10				10. Leuchs.
BIRCH, common of Europe (*Betula alba*)	Body-wood		Dry	0.85	(mean of 89 expts.)				30. Chevandier.
	Ditto, from tree of 60 years		Dried at 140°	0.70					31. Chevandier.
	Body-wood		Dried at 100°	0.86		8.66	25.22	3.99	38. Wittstein.
	do.		Dry	1.39	10.56				52 Leipzig œk. Gess.
	do.			1.08	11.63				1. v. Werneck.
	do.				16 41				19. Simon.
	do.				12 50				59. Uhden.
	do.			1.05	11.90				40. Hohenstein.
	do.		Dry	0.99					Baer, Jahresbericht, **1.** 1112.
	do.		Fresh Dry	1.00 1.14					20. Brix.
	do.					12.81	39.29	8.13	37. Witting.
	Ditto, from another locality					5.67	27.53	4.22	
	Ditto, from still another locality					14.78	18.08	16.65	
	Fagots		Air dried	1.00	16.00	12.72 †	28.76	3.30	4. Berthier.
	Boughs and twigs				16.49				19. Simon.
	Bark			5.90					42. Schulze.
	Roots		Dry	2.17	10.67				52. Leipzig œk. Gess.
	Leaves	August	Air dried	4.99					60. Sprengel.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* Mean of entire year.

† Perhaps containing some soda.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
BIRCH — *continued*	Leaves		Dried at 100°	3.99		7.94	11.95	20.02	38. Wittstein.
	Wood from branches of a tree of 60 years		Dried at 140°	1.03					31. Chevandier.
	Wood from twigs of the 60 year old tree		Dried at 140°	0.60					
	Leaves & tips of twigs	29 July	Dried at 100°	3.52					61. Stoeckhardt.
BLACKBERRY, common of Europe (*Rubus fruticosus*)	Stalks ½ to 1½ c.m. thick, with their bark	March			29.00	28.96	00.00	14.33	13. Malaguti and Durocher.
	Fruit		Fresh	0.49					18. Fresenius's pupils.
BOX (*Buxus sempervirens*)	Body-wood		Dry	2.88					53. Régie.
	do.		Dry	2.90	7.80				27. Kirwan.
	Branches ½ to 1½ c.m. thick, with bark	Oct.			19.00	14.18	00.00	11.23	13. Malaguti and Durocher.
	Large roots				15.10		25.38	4.75	3. Gueymard.
	Small roots				9.24		29.37	5 46	
	Leaves and twigs				10.00		34.89	4.85	
	do.	Autumn	Dry	9.37	14.48		?	1.90	12. Gueymard.
BROOM (*Spartium scoparium*)	Whole plant above root			1.48	12.86				1. v. Werneck.
	do.			1.48	11.86				40. Hohenstein.
				1 50	13.33				
	do.	End Oct.	Fresh	0.62					26. Sprengel.
	do.	End Oct.	Air dried	1.18					
	do.	August	Complty.dry	2.25		38.49	19.58	10.57	Merz, Versuch-Stationen, **1.** 87.
	do.	May			33.33	23.06	00.00	13.46	13. Malaguti and Durocher.
BUCKTHORN (*Rhamnus frangula*)	Peeled branches, 1 c.m. in diam., from powder works		Air dried	0.20*–0.25	26.00				4. Berthier.
	do.		Dried at 150°	0.19					Violette.
BUCKTHORN (*Rhamnus cathartica*)	Entire plant above root			1.66	9.00				40. Hohenstein.
CACAO (*Theobroma cacao*)	Beans freed from shells								
	Guayaquil			3.03					Tuchen, cited in Amer. Journ. Pharm., 1860, **32.** 544.
	Surinam			3.00					
	Caraccas			2.92					
	Para			3.00					
	Maragnow			2.92					
	Trinidad			2.98					
	Beans freed from shells		Dried at 100°	3.63		37.14	00.00	39.63	9. Zedeler.

* "Yields least ash of any air-dried wood" (Berthier, Ann. Ch. et Phys., [2.] **59.** 255). Both Berthier's and Violette's determinations were made upon charcoal, and thence calculated into terms of wood. See beyond.

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	
CACAO — *continued*	Seeds		Dried at 100°	3.87		30 27		38.18	Rost van Tonningen, Hoffmann's Jahresbericht, 1861, **4.** 61.
	Fruit		Dried at 100°	13.34		47.48		7.14	
	Leaves		Dried at 100°	14.58		13 71		5 21	
	Bark		Dried at 100°	12.86		13.30		23.61	
CALISAYA BARK. See Peruvian Bark.									
CANDLE NUT (*Aleurites triloba*)	Oil cake		Air dried of commerce	8.96 9.06					Th. Dietrich, Hoffmann's Jahresbericht, 1870-71, **3.** 19.
	do.		do.	9.20					Kreusler, do.
CAROB TREE (*Ceratonia siliqua*) "St. John's Bread"	Husks & seeds together		Air dried Dried at 100°	1.74 1.03					Furstenberg, cited by (2) Henneberg, 1862, Supp., p 85.
	Husks		Air dried	3.17				About 0.24	Anderson, cited by (2) Henneberg, 1862, Supp., p. 86.
CAUTO BARK. See Hirtella.									
CEDAR (compare Juniper)									
Cedrela febrifuga	Bark					0.07	31.25	1.26	Lindau, Hoffmann's Jahresbericht, **4.** 56.
CHERRY, wild or wood cherry of Europe (*Prunus avium*)	Body-wood			0 28		20.78	17.56	7.73	47. Engelmann.
	Branches of 1 to 2 c.m. diam., with their bark	Oct.			14.83	10 41	00.00	4.91	13. Malaguti and Durocher.
	Bark from body-wood.			10.37		7.46	5.87	3.26	47. Engelmann.
CHERRY, cultivated	Tree about 30 years old	Oct.	Dried by steam-heat, and then left in air at 80°.*						
	Wood, without bark, from trunk	Oct.	do.	0.30					Violette, Annales de Chimie et Phys., 1853, **39.** 297-299.
	do., from large branch	Oct.	do.	0.35					
	do., from medium sized branch	Oct.	do.	0.13					
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* Thus dried, the fresh leaves lost 60% of water, and the fresh branches 45%.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
CHERRY — *continued.*	Wood, without bark, from small branch	Oct.	Steam-dried, &c.	0.30					
	do., from large root	Oct.	do.	0.23					
	do., from medium sized root	Oct.	do.	0.22					
	Leaves	Oct.	do.	7.12					
	Hair-roots	Oct.	do.	5.01					
	Bark from trunk	Oct.	do.	2.66					
	Bark from large branch	Oct.	do.	2.90	. . .	. . .	. . .	. . .	Violette, Annales de Chimie et Phys., 1853, **39.** 297-299.
	Bark from medium sized branch	Oct.	do.	3.68					
	Bark frm small branch	Oct.	do.	3.45					
	Bark from large root	Oct.	do.	1.13					
	Bark from medium sized root	Oct.	do.	1.64					
	Wood	. . .	. . .	. . .	32.00	. . .	26.90	5.00	3. Gueymard.
	Entire fruit	. . .	Fresh	0.93 0.64 0.35	. . .	. . .	. . .	. . .	11. Margold.
	do.	. . .	Fresh	0.69 0.91 0 68 0.63	. . .	. . .	. . .	. . .	18. Fresenius's pupils.
	do.	. . .	Fresh	0.43	. . .	47.39	10.06	14.95	17. Richardson.
	Stems of the fruit	. . .	. . .	2.37	. . .	37.13	18.19	13.90	
CHESTNUT, common of Europe (*Castanea vesca*)	Copse-wood	. . .	. . .	. . .	14.60	10.11 *	29.07	1.21	4. Berthier.
	Leaves, fallen of	Autumn	Dry	5.34	2.93	. . .	?	5.81	12. Gueymard.
	Entire fruit	. . .	Fresh	0.99	. . .	36.09	9.25	7.74	17. Richardson.
	do.	. . .	Green	1.32	56.62	. . .	. . .	. . .	10. Cited by Leuchs.
	do.	. . .	. . .	1.75	. . .	. . .	. . .	. . .	König, Hoffmann's Jahresbericht, 1870-72, p. 10.
	do.	. . .	Dry	3.22	60 56	. . .	. . .	. . .	10. Cited by Leuchs.
	do.	. . .	Dry	1.45	62.07	. . .	?	10.15	12. Gueymard.
	Kernels of nuts	. . .	Dried at 110°	3.02	. . .	44.70	21.17	14.29	E. Dietrich, Jahresbericht, **19.** 706.
	Shells of nuts	. . .	Dried at 110°	1.85	. . .	2 31	18.95	8.55	
	do.	. . .	Green	0 63	70.00	. . .	. . .	. . .	10. Cited by Leuchs.
	Prickly outer husks of nuts	. . .	Green	0 88	24.41	. . .	. . .	. . .	
	do.	Autumn	Dry	5.17	14.12	. . .	?	5.57	12. Gueymard.
Chimaphila umbellata (Pipsissewa, "winter-green")	Leaves	. . .	Dry	5.24	. . .	. . .	. . .	. . .	S. Fairbank, Amer. Journ. Pharm., 1860, **32.** 257.

* Perhaps containing some soda.

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
CINCHONA. See Peruvian Bark.									
CINNAMON	Bark of 1st quality		Dried at 110°	5.12		12.11	26.66	2.64	Schäz'er, Jahresbericht, **15.** 514.
CITRON (*Citrus medica*)	Seeds					33.19	1.82	34.08	43. Souchay.
COFFEE (*Coffea Arabica*)	Berry			3.19		42.11	15.27	11.24	48. Levi.
	Berry, West Indian		Dried at 104°	3.30	40.81	15.24	7.70	37.66	T. J. Herapath, Chemical Gazette, 1848, **6.** 159.
	Berry, Plantat'n Ceylon					55.10	14.74	10.36	
	Berry, Native Ceylon					52.72	16.93	11.60	
	Berry, Java					54.00	18.13	11.05	Graham, Stenhouse & Campbell, Journal London Chemical Society, 1857, **9.** 44.
	Berry, Costa Rica					53.20	16.34	10.80	
	Berry, Jamaica					53.72	16.54	11.13	
	Berry, Mocha					51.52	16.98	10.15	
	Berry, Neilgherry					55.80	14.92	10.85	
Cola acuminata	Nuts			3.20					Attfield, Jahresbericht, **18.**632.
COW-BERRY (*Vaccinium Vitis-Idæa*)	Leaves		Dry	4.69	8.83				10. Cited by Leuchs.
	do.	Feb.	Dry	5.25	13.90				
	Wood ?			0.68	11.11				40. Hohenstein.
CURRANT (*Ribes rubrum*)	Fruit		Fresh	0.55 0.80 0.81 0.66 0.84					18. Fresenius's pupils.
DOG-WOOD, common of Europe (*Cornus sanguinea*)	Wood			0.60	12.50				40. Hohenstein.
EBONY	Wood, 1st quality		Air dried	1.50 – 1.60					4. Berthier.
EBONY, False. See Laburnum.									
ELDER, common of Europe (*Sambucus nigra*)	Body-wood			2.00	20.30				10. Cited by Leuchs.
	do.			1.38	8.14 ?				40. Hohenstein.
	do.		Dry	2.00	17.56				52. Leipzig œk. Gess.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
ELDER — *continued*	Stem							10.50	49. Vogel.
	Branches		Air dried	1 64	31.50	21.11 *	29.77	5.16	4. Berthier.
	Roots			1.64	17.13				10. Leuchs.
	do.			1.78	14.00				52. Leipzig œk. Gess.
	Leaves							13.60	49. Vogel.
	Fruit							20 30	
	Pith		Dry	2.77					25. John, p. 60.
ELDER, Dwarf (*Sambucus Ebulus*.	Entire plant	Sept. when fruit was beginning to redden.	Green Green	4.20 3.02					54. Pertuis.
ELM, common of Europe (*Ulmus campestris*)	Body-wood		Dry	2.35	16.60				27. Kirwan.
	do.		Dry	2.37					53. Régie.
	do.			2.28	12.09				1. v. Werneck.
	do.			2.30	13.04				40. Hohenstein.
	do.		Dry	2.27	14.23				52. Leipzig œk. Gess.
	do.				16.40				19. Simon.
	do.					15.19	32.88	2.15	50. Wrightson.
	do.					14.35	22.32	2.97	
	Branches and twigs				16.72				19. Simon.
	Branches of 1 to 2 c.m. diam., without bark	June			29.55	24.08	00.00	9.61	13. Malaguti and Durocher.
	Small twigs with their leaves		Dry	9.89	7.63		?	4.60	12. Gueymard.
	Clippings	July	Green	6.73					54. Pertuis.
	do.	July	Weigh'd grn., burnt ¾ dry	3.49					
	Leaves	August	Air dried	9.80					60. Sprengel.
	Bark					1.55	31.91	1.33	50. Wrightson.
	Roots		Dry	2 10	15.00				52. Leipzig œk. Gess.
ELM, Wych Ulmus *montana*)	Clippings	July	Green	6.73					54. Pertuis.
	do.	July	Weigh'd grn., burnt ¾ dry.	3.49					
— (*Ulmus effusa*)	Leaves & tips of twigs	29 July	Dried at 100°	7.64					61. Stoeckhardt.
FERNS. Tree Fern (*Cyathea canaliculata*) from Tahiti	Section of stem without pith		Dried	7.56 7.60					Hawes, Amer. Journ. Science, 1874, 7. 585.
	Bark-like portion of the stem		Dried	6.49					

* K_2O and Na_2O.

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	
FERNS — *continued.* The common ferns of Europe have been repeatedly analyzed. Some of the results are as follows:—									
Male-Fern (*Aspidium filix-mas*)	Entire plant above root	August	Complty. dry	6.34		38.03	19.03	5.69	Barop, Versuchs-Stationen, 1. [88.
	do.	Oct.	Dried at 100°	9.20	58.80	33.10	15.24	2.10	Struckmann, Jahresbericht, 9. 687. [1864, 6. 50.
	do.	May or June	Dry	7.94		48.30	00.00	15.60	Weinhold, Versuchs-Stationen,
	Root		Dried at 100°	3.19		6.78	13.05	14.87	Spiess, Hoffmann's Jahresbericht, 3. 59.
— (*Aspidium marginale*)	Part of the woody rhizoma		Dried	5.19 / 5.17					Hawes, Amer. Journ. Science, 1874, 7. 585.
Common Brake (*Pteris aquilina*)	Entire plant	Sept.	Air dried	3.70					60. Sprengel.
	do.			2.81 / 2.98	36 45 / 39.31				v. Werneck, cited by (25) John.
	do.	August		3.65	11 60				Home, cited by (27) Kirwan.
	do.				12.50				Wildenheim, cited by (27) Kirwan.
	do.				13.20				52. Leipzig œk. Gess.
	do.			4.00	15.40				10. Leuchs.
	do.	Autumn	Dried in field	4.50 / 5.00	0.70			0.46	4. Berthier.
	do.	End Sep.			22.00	19.48	00.00	5.15	13. Malaguti and Durocher.
(*Asplenium trichomanes*)	Entire plant	End June			31.45	25.82	00.00	10.13	
(*Asplenium filix-femina*)	do.	Oct.	Dried at 100°	8.10	61 00	29.56	15.34	2.77	Struckmann, Jahresbericht, 9. 687. [6. 50.
Do. do.	do.	May or June	Dry	6.41		45.50	00.00	20 00	Weinhold, Versuchs-Stationen,
(*Blechnum spicant*)	do.	End June			41.80	23.65	00 00	1.76	13. Malaguti and Durocher.
Mixture of several kinds of ferns			Dry	11.88 ?	12.63				Delkeskamp, cited by (10) Leuchs.
"Fern"	Entire plant	July	Green	2.50					
Do.	do.	August	Dry	5.01	12.50				54. Pertuis.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Fig (*Ficus carica*)	Leaves		Dry	10.74		11.45	23.06	4.31	Schafer, Jahresbericht, **17.** 608.
	do.		Fresh	0 29					
	Fruit					23.11	16.75	1.29	17. Richardson.
Fir, Silver Fir of Europe (*Abies picea*)	Body-wood			0.34	13.23				10. Cited by Leuchs.
	do.		Dried at 100°	0.33	18.72	7.69	?	Not a large amount	34. Hertwig.
	do.				19.09				59. Uhden.
	do.			1.72	12.48				1. v. Werneck.
	do.				11.45				19. Simon.
	do.			1.68	11.94				40. Hohenstein.
	Wood of a medium sized tree	Autumn	Dried at 100°	0.55		$Na_2O = 13.97$ $K_2O = 2.31.$	00.00	3.56	51. Sacc.
	Bough on which mistletoe was growing					7.66	20.23	9.13	Reinsch, Jahresbericht, **13.** 542.
	Body-wood					7.17	31.00	3.07	48. Levi.
	Bark		Dried at 100°	1.79	2.95			More than in the wood	34. Hertwig.
	Needles		Dried at 100°	2.31	29.09			do.	
	Green needles & small twigs		Air dried	3.15					60. Sprengel.
	Needles			7.10		11.13	00.00	6.89	42. Schulze.
	do.					"Much".			25. John, pp. 59 and 148 note.
	Seeds			4.47		18 57	15.91	33.85	Poleck, Annalen der Chemie und Pharmacie, 1844, **50.** 414.
	Cones					"Very much"			25. John, p. 148 note.
Furze, common of Europe (*Ulex Europæus*)	Entire plant above root		Fresh	4.00					Blythe, Hoffmann's Jahresbericht, 1866, **9.** 321.
	do.	Early in May			36.76	28.17	00.00	8.63	13. Malaguti and Durocher.
Furze, Dwarf (*Ulex nanus*)	Young twigs	Sept.	Fresh	0.94					26. Sprengel.
	do.	Sept	Air dried	1 88					
	Entire plant above root	Oct			35.90	33.34	00.00	10.04	13. Malaguti and Durocher.
Genista (*G. tinctoria*)	do.	Summer	Fresh	1.44					26. Sprengel.
	do.	Summer	Air dried	3.42					
	do.			1.62	12.34				40. Hohenheim.
	do.	May	¾ dry	2.00					54. Pertuis.
	do.	July			41.85	42.84	00.00	9.07	13. Malaguti and Durocher.
G. pilosa	Green leaves & twigs	Sept.	Fresh	1.14					26. Sprengel.
	do.	Sept.	Air dried	2.48					
G. Anglica	Entire plant abv. roots	June.	Fresh	1.16					
	do.	June.	Air dried	4.61					
G. Germanica	do.			1 62	11.38				1. v. Werneck.

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of: "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
GOOSEBERRY (*Ribes glossularia*)	Fruit		Fresh	0.39		33.73	15.20	17.92	17. Richardson.
	do.		Fresh	0.22 0.21 0.20					11. Margold.
	do.		Fresh	0.46 0.52 0.75 0.30 0.45 0.69					18. Fresenius's pupils.
GRAPE VINE (*Vitis vinifera*)	Wood			2 53		21.68	36.79	10.39	Hruschauer, Annalen der Chemie und Pharmacie, 1845, **54.** 331.
	do.			2.25		17.60	29.63	13.80	
	do.			2.33		19.32	27.07	12.34	
	do.			2.84		12.55	24 47	3.79	48. Levi.
	do.			2.69		19.28	16.51	14.41	
	do.			2.97		22.50	00.00	20.81	
	do.			2.77		28.20	00.00	12.87	Albert, Hoffmann's Jahresbericht, **8.** 119.
	do.			2.68		31.00	00.00	9.29	
	do.			3.69		44.15	00.00	7.05	
	do.				7.65		35.76	5 08	3. Gueymard.
	do.				10.33		33.51	6.28	
	Wood free from bark		Dried at 37°	1.65	50.00				25. John, p. 115.
	Wood		Dry	2.41	18.25		?	5.12	12. Gueymard.
	Stock, 6 or 7 years old, with all the leaves of the year		Air dried	5.89	23.00	Of which 16.40 is alkaline carbonate	?	8.02	Berthier, Annalen Chemie und Pharmacie, 1852, **82.** 133.
					21.00				
	Shoots		Dry	3.38					53. Régie.
	do.		Air dried	3.50	21.00	13.80 *	31.49	6.15	4. Berthier.
	do., from another locality		Air dried	4.20		65.70% of the soluble matter *		More than the preceding	
	Shoots				29.24		28.14	10.09	3. Gueymard.
	do.	Spring	In the state in which they were when cut	2.44		18.00	30.70	10.40	Boussingault, Annales Chimie et Physique, 1850, **30.** 370.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* Perhaps containing some soda.

1.		2.	3.	4.	5.	6.	7.	8.	9.	10.
GRAPE VINE — *continued*	I.	Nodes or knots of shoots of previous summer	Feb. . .	Dried at 100°	3.38	. . . .	16.98	. . . .	9.45	Nessler, Versuchs-Stationen, 1873, **16.** 186. The samples numbered I. grew upon unmanured land; those numbered II. were manured with gypsum; No. III. was manured with sulphate of potash; No. IV. with chloride of potassium; & No. V. with a mixture of KCl, $(NH_4)_2SO_4$, and superphosphate.
	I.	Part between the knots from do.	Feb. . .	Dried at 100°	2.89	. . . .	16.76	. . . .	9.02	
	II.	Nodes or knots of do. .	Feb. . .	Dried at 100°	3.69	. . . .	17.20	. . . .	8.43	
	II.	Part between knots, do.	Feb. . .	Dried at 100°	2.80	. . . .	20.72	. . . .	8.99	
	III.	Nodes or knots of do. .	Feb. . .	Dried at 100°	3.32	. . . .	22.99	. . . .	7.76	
	III.	Part between knots, do.	Feb. . .	Dried at 100°	2.62	. . . .	23 25	. . . .	7.34	
	IV.	Nodes or knots of do. .	Feb. . .	Dried at 100°	4.33	. . . .	22.30	. . . .	9.85	
	IV.	Part between knots, do	Feb. . .	Dried at 100°	2.90	. . . .	24.45	. . . .	10.48	
	V.	Nodes or knots of do. .	Feb. . .	Dried at 100°	2.89	. . . .	22.89	. . . .	12.06	
	V.	Part between knots, do.	Feb. . .	Dried at 100°	2.51	. . . .	24.58	. . . .	12.02	
		Shoots that had been reduced to powder by worms	. . . .	Dry . . .	3.00	. . . .	. . . .	. . . .	. . . .	16. Pissis.
		Branches 1 c.m. thick, with swollen but not yet developed buds .	April. .	. . . .	. . . .	32.34	28.54	00.00	15.07	13. Malaguti and Durocher.
		Branches ("treillage")	. . . .	Dry . . .	1.81	57.05	. . . .	?	9.38	12. Gueymard.
		Branches 1 & 2 yrs. old	Late in Autumn	Dried at 100°	2.85	. . . .	25.66	29.33	6.60	Crasso, Annalen Chemie und Pharmacie, 1846, **57.** 68.
		Ditto, from another locality	Late in Autumn	Dried at 100°	3.77 3.62	. . . .	39.37	11.00	6.29	Crasso, Annalen Chemie und Pharmacie, 1847, **62.** 68.
		Branches	. . . .	. . . .	3.40	14.84	. . . .	. . . .	. . . .	10. Cited by Leuchs.
		Branches	. . . .	Dry . . .	3.40	16.26	. . . .	. . . .	. . . .	27. Kirwan.
		Pith of branches, free from wood	Late in Autumn	Dried at 100°	4.81 4.80	. . . .	. . . .	. . . .	. . . .	Crasso, Annalen der Chemie und Pharmacie, 1846, **57.** 70.
		Wood of branches, free from pith	Late in Autumn	Dried at 100°	2.45 2.49	. . . .	. . . .	. . . .	. . . .	
		Leaves	Taken from the vine in October .	Dry . . .	7.50	15.60	. . . .	?	4.59	12. Gueymard.
		Leaves	. . . .	. . . .	3.38	16.29	. . . .	. . . .	. . . .	40. Hohenstein.
		Fruit	. . . .	Dry . . .	2.00	18.50	Of which 13.50 is alkaline carbonate .	?	10.68	Berthier, Ann. Chem. Pharm. 1852, **82.** 133.
		Fruit	. . . .	Fresh . . .	0.45 0.40 0.33	. . . .	. . . .	. . . .	. . . .	11. Margold.

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
GRAPE VINE — *continued*	Fruit		Fresh	0.48, 0.45					18. Fresenius's pupils.
	Wine		Liquid	0.19		45.03	13.69	22.03	Boussingault, Annales Chimie et Physique, 1850, **30.** 370.
	Fresh juice of unripe grapes		Fresh	0.31					6. Sprengel, citing Geiger.
	Fresh juice	13 Sept.	Fresh	0.26		55.18	17.60	12.79	Crasso, Annalen Chemie und Pharmacie, 1847, **62.** 60.
	do.	22 Oct.	Fresh	0.34		49.42	21.99	12.60	
	Fresh juice from another kind of grape	22 Oct.	Fresh	0.29		50.18	19.87	13.63	
	Ditto, from another locality	28 Oct	Fresh	0.41		54.81	20.65	10.74	
	Fresh skins of fruit	22 Oct.	Dried at 100°	3.75, 3.74		32.75	21.93	15.40	
	Ditto, from another kind of grape	22 Oct.	Dried at 100°	4.32		36.94	19.43	12.34	
	Seeds	22 Oct.	Dried at 100°	2.73, 2.83		23.66	13.94	22.93	
	Seeds of the other kind of grape	22 Oct.	Dried at 100°	2.88, 2.79		23.78	17.29	17.00	
	Dregs from wine-making (Weinhefen)		Dry	16.67 *	50.00				10. Leuchs, p. 103.
	Skins of grapes after the juice has been expressed and the refuse distilled for brandy.		Dry	20.00 *	10.00				
	do. do.				11.50, 10.50, 7.50, 9.50				Chevallier, Dingler's Polytech. Journal, 1851, **121.** 468.
	Residue from wine-making ("marc de raisin")		Air dried	6.65		36.90	27.70	10.70	Boussingault, Annales Chimie et Physique, 1850, **30.** 370.
GUARANA (*Paullinia sorbilis*)	Seeds without shells			1.70		1.87 and much soda	18.63 +	4.96	Peckholt, Jahresbericht, **19.** 708.
	Shells of seeds			10.19					
GUELDER-ROSE. See under Wayfaring-Tree.									
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* Together with much dirt ?

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
HAWTHORN (*Cratægus oxyacantha*)	Wood			1.14	7.71				1. v. Werneck.
	do.		Air dried	0.50					4. Berthier.
— *Cratægus terminalis*, Wild Service Tree	do.		Dry	0.68					Baer, Jahresbericht, 1. 1112.
	Branches 1 to 2 c.m. thick	Oct			12.36	9.25	00.00	4.47	13. Malaguti and Durocher.
	Sap-wood without bark		Dry	0.44	14.29			"Very little"	25. John, pp. 141, 142.
	Half-rotten sap-wood (in condition of punk) from same log as the foregoing		Dry	1.19	47.37				
HAZEL-NUT, common of Europe (*Corylus avellana*)	Body-wood		Dry	3.00	9.09				52. Leipzig œk. Gess.
	do.				13.90				4. Berthier.
	Branches		Air dried	1.57	15.40	11.27 *	35.44	3.29	
	Branches, 1 c.m. thick, without bark	1 May	Dried at 25°	0.50	24.50				45. De Saussure.
	Bark from the branches aforesaid	1 May	Dried at 25°	6.20	12.50				
	Leaves	1 May	Dried at 25°	6.10	26.00				
	do.	22 June.	Dried at 25°	6.20	22.70				
	do.	22 June.	Fresh	2.80					
	do.	20 Sept.	Dried at 25°	7.00	11.00				
	do.	20 Sept.	Fresh	3.10					
	Leaves of May 1 washed with distilled water		Dried at 25°	5.70	8.20				
	Leaves & tips of twigs	29 July	Dried at 100°	5.15					61. Stoeckhardt.
	Roots		Dry	3.27	8.67				52. Leipzig œk. Gess.
HEATH, common of Europe (*Erica vulgaris*)	Entire plant above root			1.41	11 51				1. v. Werneck.
	do.			1.40–1.45	10.35-10.72				40. Hohenstein.
	do.		Air dried	1.80	13.40	7.96	?	5.96	4. Berthier, Voie sèche.
	do.	June.	Half dry	2 41					54. Pertuis.
	do.	June.	Green	2.44					
	do.				10.00				59. Uhden.
	do.				11.50				Wildenheim, cited by (27) Kirwan.
	do.		Air dried	1.96					60. Sprengel.
	do.				17.50				10. Leuchs.
	do.	End Aug.	Dried at 100°	6.35		10.65	00.00	10.89	Röthe, Annalen Chemie und Pharmacie, 1853, 87. 119.

* K_2O and Na_2O.

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	
HEATH — *continued*	Entire plant above root	Oct.			37.21	2.71	00.00	0.60	13. Malaguti and Durocher.
	do.			4.50		4.81	00.00	0.61	Wiegman, cited by (42) Schulze, pp. 78, 88.
	do.				3.89				52. Leipzig œk. Gess.
	do. including seed	Oct.	Green	2.88					54. Pertuis.
	Entire plant above root	Aug. when in flower.	Air dried	2.88		6.42	00.00	4.01	Nutzinger, Jahresbericht, **8.** 722.
	do. from another locality	do.	Air dried	3.32		29.58 *	00.00	5.30	Thielau, Jahresbericht, **8.** 722.
(*Erica carnea*)	Entire plant	June.	Dried at 100°	2.66		18.07	17.69	4.47	Röthe, Bericht d. Naturhistorischen Vereins in Augsburg, 1853, **6.** 27.
(*E. cinerea*)	do.	Sept.			30.09	11.88	00.00	6.29	} 13. Malaguti and Durocher.
(*E. ciliaris*)	do.	Sept.			24.85	7.61	00.00	4.19	}
(*E. herbacea*)	Plant without fruit		Dried at 100°	1.30		12.05	14.13	18.28	} 23. Hruschauer.
	do.		Dried at 100°	0.84		28.61	16.60	9.68	}
(*E. tetralix*)	Entire plant	End June			21.29	14.65	00.00	3.86	13. Malaguti and Durocher.
Hirtella silicia (Cauto-bark of Trinidad)	Bark		Air dried	34.40		0.44	Over 96% of SiO_2.		28. Wicke.
HOLLY, common of Europe (*Ilex aquifolium*)	Leaves		Dried at 100°	4.30		14.27	28.50	3.63	Reithner, Jahresbericht, **8.** 723.
	Branches and leaves	May	¾ dry	3.28					54. Pertuis.
(*Ilex Paraguensis*), Paraguay Tea	Leaves			3.90		26.84	00.00	4.31	Strauch, Jahresbericht, **20.** 770.
HORNBEAM, common of Europe (*Carpinus betulus*)	Body-wood		Dry	1 13	11.10				53. Régie.
	do.			1.14	11.29				1. v. Werneck.
	do.			1.12	12.92 }				10. Leuchs.
	do.			1.10	11.36 }				
	do.		Dry	2.53	12.75				52. Leipzig œk. Gess.
	do.		Dry	1.62	(mean of 73 expts.)				30. Chevandier.
	do.		Dry	0.87					Baer, Jahresbericht, **1.** 1112.
	do.				21 99				19. Simon.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* K_2O and Na_2O.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
HORNBEAM — *continued*	Body-wood					10.63	00.00	10.74	42. Schulze.
	Wood		Fresh	2.17					20. Brix.
			Dry	2.48					
	Copse-wood				18.90		?	7.24	4. Berthier.
	do				17.20	8.71	29.52	6.83	
	Boughs and twigs				22.12				19. Simon.
	do.			1.25	10.00				40. Hohenstein.
				1.10	11.36				
	Twigs			2.51	13.20				10. Leuchs.
	Heart-wood, from tree 40-50 years old, free from sap-wood		Air dried	0.41					5. Sprengel.
	Heart-wood from trunk 6 inches thick	Nov.	Dried at 25°	0.60	22.00				45. De Saussure.
	Sap-wood of do.	Nov.	Dried at 25°	0.70	18.00				
	Bark of do.	Nov.	Dried at 25°	13.40	4.50				
	Small branches	May	Dry	2.14					54. Pertuis.
	Roots		Dry	2.42					52 Leipzig œk. Gess.
	Buds collected at moment when they had begun to develop		Dry	4.22					54. Pertuis.
	Leaves & tips of twigs	29 July	Dried at 100°	5.28					61. Stoeckhardt.
	Leaves	August	Air dried	6.16					6. Sprengel.
	Leaves, fallen of	Autumn	Dry	12.47	5.21		?	3.93	12. Gueymard
HORSE-CHESTNUT — (*Æsculus Hippocastanum*)	Wood				16.12				19. Simon.
	Body-wood & branches	10 May	Dried at 25°	3.50	9.50				45. De Saussure.
	Wood of 1 yr. old shoots	19 May	Dried at 100°	1.05	29.21	19.44	24.16	14.58	55. Wolff.
	ditto	1 Sept.	Dried at 100°	3.38		19.42	00.00	21.73	56. Staffel.
	Young shoots	6 May	Dried at 100°	10.91		64.18	00.00	19 02	
	Leaves	6 May	Dried at 100°	7.69		49.32	00.00	24.40	
	do.	10 May	Dried at 25°	7.20	50.00				45. De Saussure.
	do.	10 May	Fresh	1.60					
	Leaves, just unfolded	18 May	Dried at 100°	9.08	39.77	24.28	12.89	19.48	55. Wolff.
	Stalks of leaves	13 May	Dried at 100°	13.87	59.38	38.43	16 78	12.32	
	Leaves	23 July	Dried at 25°	8.40	24.00				45. De Saussure.
	do.	23 July	Fresh	2.90					
	do.	1 Sept.	Dried at 100°	7.52		29.57	00.00	8.22	56. Staffel.
	do.	27 Sept.	Fresh	3.10					45. De Saussure.
			Dried at 25°	8.60	13.50				
	Flower Stalks	17 May	Dried at 100°	11.36	81.16	52.77	17.64	14.07	55. Wolff.
	Calyx and Ovary	16 May	Dried at 100°	6.65	72.70	48.04	22.17	12.94	

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	
HORSE-CHESTNUT — *continued*	Stamens	16 May	Dried at 100°	6.56	72.17	47.69	21.47	15.33	55. Wolff.
	Petals	16 May	Dried at 100°	6.06	72.20	48.00	21.58	13.31	
	Flowers	10 May	Dried at 25°	7.10	50.00				45. De Saussure.
	do.	10 May	Fresh	0.90					
	Green fruit	20 June.	Dried at 100°	4.39	77.77	49.50	15.75	17.55	55. Wolff.
	Mature fruit	5 Oct.	Dried at 25°	3.40	75.00				45. De Saussure.
	do.	5 Oct.	Fresh	1.20					
	Fruit			2.35	71.07				10. Leuchs.
	do.					"Very much"			25. John, p. 148, note.
	Mature fruit with some husks		Fresh	1.18		More than 33.65			D'Arcet, Annales de Chimie, 1811, 79. 146.
	Mature fruit				60.65	More than 37.39			
	Husks of mature fruit				46.00	More than 31.21			
	Entire fruit with husks	Oct.	Air dried	3.49	50.07				
	Kernels of ripe fruit, free from green and brown shell.	End Sep.	Dried at 100°	3.36	78.85	50.73	17.83	18.74	55. Wolff.
	Ditto, from another locality	End Sep.	Dried at 100°	2.26	77.02	48.90	13.07	19.15	
	Green shell of ripe fruit	End Sep.	Dried at 100°	7.29	85.37	57.21	24.61	3.98	
	Ditto, from another locality	End Sep.	Dried at 100°	4.53	81.96	55.41	27.97	5.40	
	Brown shell of ripe fruit	End Sep.	Dried at 100°	2.20					
	Ditto, from another locality	End Sep.	Dried at 100°	1.70	68.77	43.32	18.88	15.36	
	Bark of young shoots	6 May	Dried at 100°	8.68		61.00	00.00	19.54	56. Staffel.
	Bark of year old shoots	19 May	Dried at 100°	7.85	11.35	7.53	37.92	3.75	55. Wolff.
	Outer portion of such bark	19 May	Dried at 100°	5.58					
	Inner portion of such bark	19 May	Dried at 100°	2.27					
	Bark of year old shoots	1 Sept.	Dried at 100°	6.57		24.19	00.00	6.95	56. Staffel.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
IVY, common of Europe (*Hedera helix*)	Wood						00.00	9.22	58. Herapath.
	do.	Oct.	Dry	3.95	6.33				10. Leuchs.
	do.	Autumn		1.52	11.47				40. Hohenstein.
	Leaves	Oct.	Dry	5.92	33.30				10. Leuchs.
	do.	Feb.	Dry	9.42	20.80				
	Branches with leaves	Autumn	Dry	5.87	15.48		?	3.87	12. Gueymard.
	Berries						00.00	26.49	58. Herapath.
IVY, POISON. See Sumach.									
JASMINE, common of France	Clippings	July	Green	6.73					54. Pertuis.
	do.	July	¾ dry	3.49					
JUDAS TREE, European (*Cercis siliquastrum*)	Branches of medium size		Air dried	1.70	19.00	16.40 *	32.52	5.50	4. Berthier.
JUNIPER (*Juniperus communis*)	Bushes			1.84	8.47				1. v. Werneck.
	do.	May	¾ dry	3.56					54. Pertuis.
	do.	Sept.	Dry	4.03					
LABURNUM (*Cytisus alpinus*)	Medium sized branches		Air dried	1.25	31.50			11.81 14.76	4. Berthier, p. 257. B. remarks on the large proportion of P_2O_5. I have taken the second determination proportional to the first from B.'s figures.
LARCH, common of Europe (*Pinus larix*)	Body-wood				14.40				19. Simon.
	do.		Air dried	0.32		10.88	29.64	2.52	36. Böttinger.
	Needles					1.18	3.24 and much SiO_2	0.11	Karmrodt, Hoffmann's Jahresbericht, **7.** 98.
	Roots				11.62				19 Simon.
LAURESTINUS. See Wayfaring-Tree.									
LILAC (*Syringa vulgaris*)	Leaves from white-flowering Lilac		Dried at 110°	4.39		25.05	21.05	10.23	Wittstein's pupils, Jahresbericht, **20.** 769.
	Leaves from violet-flowering Lilac		Dried at 110°	4.92		23.35	5.31	25.35	

* K_2O and Na_2O.

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	
LILAC — *continued*.	White flowers without calyx		Dried at 110°	5.76		37.11	18.57	18.59	Wittstein's pupils, Jahresbericht, **20.** 769.
	Violet flowers without calyx		Dried at 110°	4.29		39.98	11.43	27.36	
	Fruit			3.64	69.65				10. Leuchs.
LINDEN, European (*Tilia rubra*)	Body-wood			1.45	6.42				1. v. Werneck.
	do.			1.42	7.00				40. Hohenstein.
	do.			3.18	5.56				52. Leipzig œk. Gess.
	Branches, medium size		Air dried	5.00	10.80	6.55 *	38.71	2.33	4. Berthier.
	Wood of branches 10 to 12 inches thick					27.86	22.26	3.77	57. Hoffmann.
	Bark			8.81					42. Schulze.
	Bark of branches 10 to 12 inches thick					11.93	26.31	2.97	57. Hoffmann.
	Leaves †	Oct.	¾ dry	6.54					54. Pertuis.
	Leaves	August	Air dried	7.99					60. Sprengel.
LINDEN, Small Leaved (*Tilia parvifolia*)	Leaves & tips of twigs	29 July	Dried at 100°	7.32					61. Stoeckhardt.
LINDEN, Large Leaved (*Tilia grandifolia*)	do.	20 July	Dried at 100°	9.30					
LINDEN, White (*Tilia alba*)	Leaves, fallen of	Autumn	Dry	8.85	4.54		?	4.24	12. Gueymard.
LOCUST, common (*Robinia pseudacacia*)	Sticks, ½ to 2 c.m. thick, with their bark	March			16.90	10.53	00.00	11.51	13. Malaguti and Durocher.
	Medium sized twigs				10.60		38.23	4.02	3. Gueymard.
	Leaves & tips of twigs	20 July	Dried at 100°	9.70					61. Stoeckhardt.
	Leaves		Dry	3.00					Hoffmann, in his Jahresbericht, 1863, **6.** 47.
	do.	August	Air dried	7.10					60. Sprengel.
	Leaves, fallen of	Autumn	Dry	8.40	24.04		?	2.24	12. Gueymard.
	Meal of locust beans		Air dried of commerce	2.87					Vœlcker, Hoffmann's Jahresbericht, 1865, **8.** 313.
MAPLE, or Sycamore of Europe (*Acer pseudo-platanus*)	Body-wood			2.79	16.49				10. Leuchs.
1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**

* K_2O and Na_2O.

† Somewhat contaminated with sand.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
MAPLE — *continued*	Body-wood			1.13	11.11				40. Hohenstein.
	do.		Dry	2.88	17.74				52. Leipzig œk. Gess.
	Heart-wood, without sap-wood, from a tree 40 to 50 years old		Air dried	0.42					5. Sprengel.
	Roots		Dry	2.14	17.82				52. Leipzig œk. Gess.
	Leaves & tips of twigs	29 July	Dried at 100°	5.08					61. Stoeckhardt.
	Leaves	August	Air dried	11.53					60. Sprengel.
Millingtonia Hortensis [*Bignoniaceæ*]	Bark		Air dried	8.70		27.23	27.97	3.87	Hollandt, cited in American Journal Pharmacy, **33.** 508.
	do.		"Anhydrous"	10.00					
MISTLETOE (*Viscum album*)	Leaves and twigs					35.32	13.63	17.60	
	Twigs			3.67					14. Fresenius and Will.
	Leaves			10.93					
	Twigs	Early in June		1.90		20.15	21.77	16.28	C. Erdmann.
	Leaves	Early in June		3.85		19.74	23.59	16.37	
	Twigs and leaves					22.03	15.27	17.76	Reinsch, Jahresbericht, **13.** 542.
MOUNTAIN ASH of Europe (*Pyrus aucuparia*)	Leaves & tips of twigs	20 July	Dried at 100°	7.10					61. Stœckhardt.
MULBERRY, White (*Morus alba*)	Branches of medium size		Air dried	1.60	15.00			9.40	4. Berthier.
	Ditto, from another locality				25.00	13.10	37.57	1.23	
	Leaves	17 April.	Fresh	2.15					
	do.	17 April.	Anhydrous	10.20					
	do.	29 April.	Fresh	1.68					
	do.	29 April.	Anhydrous	7.20					
	do.	6 May	Fresh	2.00					
	do.	6 May	Anhydrous	8.16					Bechi, Hoffmann's Jahresbericht, 1868, **11.** 163.
	do.	15 May	Fresh	3.12					
	do.	15 May	Anhydrous	8.21					
	do.	10 Aug.	Fresh	4.22					
	do.	10 Aug.	Anhydrous	12.79					
	do.	14 Aug.	Dry	11.56	19.19		?	7.78	
	Twigs, 1 year old, from which the leaves were taken	14 Aug.	Dry	3.97	36.82		?	6.95	12. Gueymard.
	Leaves, fallen of	Autumn	Dry	15.45	5.84		?	3.66	

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
MULBERRY, Black (*Morus nigra*)	Branch	When berries were partly ripe	Dried at 100°	2.61	18.79	11.67	29.01	8.42	58. Herapath.
	Heart-wood	Nov.	Dried at 25°	0.70	21.00	. . .	. . .	. . .	45. De Saussure.
	do.	. . .	. . .	0.80	. . .	. . .	. . .	. . .	58. Herapath.
	Sap-wood	Nov.	Dried at 25°	1.30	26.00	. . .	. . .	. . .	45. De Saussure.
	do.	. . .	. . .	3.60	. . .	. . .	. . .	. . .	58 Herapath.
	Bark	Nov.	Dried at 25°	8.90	7.00	. . .	. . .	. . .	45. De Saussure.
	Inner fibrous part of the bark	Nov.	Dried at 25°	8.80	10.00	. . .	. . .	. . .	
	Leaves	When berries were partly ripe	Dried at 100°	10.21	49.49	21.43	20.57	7.18	58. Herapath.
	Berries	Ptly. ripe	Dried at 100°	9.27	58.54	23.66	26.95	11.30	
	do	Ptly. ripe	Fresh	0.69	. . .	. . .	. . .	. . .	
	do., another sample from same tree	. . .	. . .	. . .	59.43	22.50	19.00	11.99	
	Berries	Ripe	Fresh	0.66	. . .	. . .	. . .	. . .	18. Fresenius's pupils.
	Leaves	20 April.	Fresh	2.15	. . .	. . .	. . .	. . .	Bechi, Hoffmann's Jahresbericht, 1868, p. 163.
	do.	20 April.	Anhydrous	8.50					
	do.	29 April.	Fresh	1.78					
	do.	29 April.	Anhydrous	6.60					
	do.	6 May	Fresh	2.16					
	do.	6 May	Anhydrous	8.00					
	do.	15 May	Fresh	2.65					
	do.	15 May	Anhydrous	7.79					
	do.	10 Aug.	Fresh	4.90					
	do.	10 Aug.	Anhydrous	14.00					
— (*Morus cucullata*)	do.	17 April.	Fresh	2.76					
	do.	17 April.	Anhydrous	12.05					
	do.	20 April.	Fresh	2.65					
	do.	20 April.	Anhydrous	11.02					
	do.	24 April	Fresh	2.32					
	do.	24 April.	Anhydrous	10.20					
	do.	6 May	Fresh	2.85					
	do.	6 May	Anhydrous	10.40					
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
MULBERRY, Chinese (*M. rubra*)	Branches				18.90	12.85 *	19.43	4.09	4. Berthier.
— (*Morus Lhou*)	Mature leaves, from a manured plot	20 July	Dried at 120°	11.67		23.10	19.92	7.49	Heidepriem, Versuchs-Stationen, 1868, **10.** 381.
	Mature leaves, from an unmanured plot	20 July	Dried at 120°	10.22		18.52	20.69	8.85	
Mulberry Leaves (variety not stated) from Japan	Long, narrow, mature leaves		Dry	12.59		22.38	6.17 †	5.96	Reichenbach, Annalen der Chemie und Pharmacie, 1867, **143.** 90.
Ditto, another kind	do.		Dry	13.58		23.04	4.46 †	5.15	
From China	Large, mature leaves		Dry	13.53		22.74	3.89 †	4.68	
From Piedmont	Mature, but not very large leaves		Dry	14.17		21.55	11.42 †	3.54	
Ditto	do.		Dry	14.45		14.76	10.58 †	3.14	
Ditto	do.		Dry	14.67		14.99	8.43 †	3 94	
From Alais, France	Large, mature leaves		Dry	11.96		23 65	14.77 †	4.46	
From Brescia, Italy	Young leaves		Dry	11.34		22.26	6.21 †	7.26	
From Bendorf	Leaves from a shady, unmanured plot		Fresh	3.35		15.40 ‡	16.32 †	9.10	Karmrodt, Hoffmann's Jahresbericht, 1858, **1.** 62.
Ditto	Leaves from a sunny, unmanured plot		Fresh	4.58		17.80 ‡	13.78 †	9.65	
Ditto	Leaves from a sunny, manured plot		Fresh	4.26		17.40 ‡	9.95 †	7.79	
From Andernach on the Rhine	Leaves	June.	Anhydrous	10.85		25.60	00.00	6.84	Karmrodt, Hoffmann's Jahresbericht, **11.** 164.
Ditto	do.	June.	Anhydrous	11.41		22.79	00.00	7.70	
Ditto	do.	June.	Anhydrous	11.45		23.17	00.00	6.18	
OAK, European (*Quercus robur*)	Body-wood		Dry	1.35	11.39				53. Régie.
	do.		Dry	1.15	6.67				Watson, cited by (10) Leuchs.
	do.				8.90				59. Uhden.
	do.		Dry	1.65	(mean of 93 expts.)				30. Chevandier.
	do.			1.40	11.86				1. v. Werneck.
	do.		Fresh Dry	1.13 1.39					20. Brix.
	do.			2.35	9.36				10. Leuchs.
	do.			1.50 1.35	9 53 11.11				40. Hohenstein.
	do.				11.10				19. Simon.
	do.		Dry	2.03					Baer. Jahresbericht, **1.** 1112.
	do.		Dry	2.35	7.56				52. Leipzig œk. Gess.

* K_2O and Na_2O. † CO_2 alone. ‡ "Alkalies."

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
OAK — *continued*	Wood from body of a tree 120 years old		Dried at 140°	2.43					31. Chevandier.
	Wood from branches of same tree		Dried at 140°	2.03					
	Body-wood				13.00				16. Pissis.
	do.					5.65	33.67	2.32	Deninger, Annalen der Chemie und Pharmacie, 1845, **54.** 343.
	do.				20.00				4. Berthier, p. 256.
	Body-wood sawdust		Dried at 60°	1.10					
	Heart-wood, from an old log		Air dried	0.68	11.54			"Very little"	25. John, p. 139.
	Rotten heart-wood from the same log		Air dried	7.50	11.11				
	Heart-wood, from a stem 8″ in diameter		Dried at 25°	0.20	38.60				45. De Saussure.
	Heart-wood from tree 40 to 50 years old		Air dried	0.21					5. Sprengel.
	Heart-wood, the internal 8 rings taken from tree 60 years old	Winter	Air dried	0.27					5. Sprengel.
	Heart-wood, taken from a point midway between centre & outside	Winter	Air dried	0.31					
	Sap-wood	Winter	Air dried	0.53					
	Sap-wood, from a stem 8 inches in diameter		Dried at 25°	0.40	32.00				45. De Saussure.
	Sticks, 5 to 15 c.m. in diameter		Air dried	2.50	12.00	8.11 *	37.87	0.73	4. Berthier.
	do.				15.50	9.43 *	33 92	5.54	
	Branches and twigs				11.22				19. Simon.
	Small branches & fagots					57% of the soluble matter was K_2O & Na_2O	29.25	0 98% of the insoluble matter was P_2O_5.	4. Berthier.
	Small branches and fagots, from another locality, burnt in a reverberatory furnace				10.00	6.52 *	24.38	5.98	4. Berthier.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* K_2O and Na_2O.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
OAK — *continued*	Small branches	May	Dry	2.51					54. Pertuis.
	Branches, from young tree, 1 c.m. thick, with bark	10 May	Dried at 25°	0.40	26.00				45. De Saussure.
	Young twigs from tree 120 years old		Dried at 140°	1.68					31. Chevandier.
	Fagots of twigs from tree of 30 years		Dried at 140°	1.45					
	Fagots of branches from tree of 50 years		Dried at 140°	1.56					
	Fagots of branches from tree of 70 years		Dried at 140°	2.10					
	Fagots of branches from tree of 130 yrs.		Dried at 140°	2.16					
	Fagots		Air dried	2.20					4. Berthier.
	Wood that had rotted to the condition of earth		Dry	3.00					16. Pissis.
	ditto		Dry	4.10	24.00				45. De Saussure.
	Leaves & tips of twigs	August		4.60		25.41	23.28	9.35	Neubauer, Versuchs-Stationen, **1.** 91.
	Leaves	10 May	Fresh	1.30	47.00				45. De Saussure.
	do.	10 May	Dried at 25°	5.30					
	do.	27 Sept.	Fresh	2.40	17.00				
	do.	27 Sept.	Dried at 25°	5.50					
	do.	August	Air dried	5.06					60. Sprengel.
	Leaves raked from beneath trees		Air dried	4.50					
	Leaves, withered of	Autumn	Air dried	4.90		3.35	00.00	8.08	28. Wicke.
	Leaves, rakings of	Autumn	Dry		0.44				52 Leipzig œk. Gess.
	Leaves			3 00	17.00				10. Leuchs.
	do.		Dry	8.01					Hoffmann, in his Jahresbericht, 1863, **6.** 47.
	Leaves, sound of	Autumn	Dry	5.00	10.71				25. John, p. 226.
	Leaves, rotten of	Autumn	Dry	5.00	14.30	9.72			
	Bark		Dry	4.60		5.30	34.48	3.11	Eckert, Jahresbericht, **17.** 608.
	Bark, as used by tanners		Air dried	6.00	5.00	3.47 *	38.67	Mere trace	4. Berthier.
	Bark of branches 1 c.m. thick, from young tree	10 May	Dried at 25°	6.00	7.00				45. De Saussure.
	Bark from a stem 8″ in diameter		Dried at 25°	6.00	7.00				
	Inner fibrous part of the last named bark		Dried at 25°	7.30	7.00				

* K_2O and Na_2O.

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
OAK — *continued*	Roots		Dry	2.47	9.71				52. Leipzig œk. Gess.
	Acorns					51.73	18.54	13.70	Kleinschmidt, Annalen Chemie und Pharmacie, 1844, **50.** 417.
	do.					54.93	14.70	11.15	Graham, Stenhouse, and Campbell, Journal Chemical Society, 1857, **9.** 47.
	do.		Fresh	1.04					Dietrich, Hoffmann's Jahresbericht, 1868, p. 488.
	do.		Fresh	2.00					Peters, Hoffmann's Jahresbericht, 1868, p. 488.
	do.		Dry	2.20					
	Shelled acorns		Dry	1.60					
	do.		Dry	2.90					Dietrich, Hoffmann's Jahresbericht, 1868, p. 488.
(*Quercus pedunculata*)	Branches, 1½ to 2 c.m. thick, with their bark	Feb.			17.00	19.83	00.00	9.33	13. Malaguti and Durocher.
	do.	Oct.			14.77	11.60	00.00	7.41	
	Leaves & tips of twigs	29 July	Dried at 100°	4.54					61. Stoeckhardt.
Holly, or Evergreen Oak (*Quercus Ilex*) "*Chêne vert*" of Berthier	Wood						?	2.18% of the insoluble part of the ashes	4. Berthier.
"*Chêne blanc*"	do.				7.50		?	2.40	
"*Chêne de Sôchilienne*"	Leaves, fallen of	Autumn	Dry	6.15	1.46		?	4.92	12. Gueymard.
OLIVE (*Olea Europæa*)	Wood		Dried at 100°	0.58		14.61	29.10	4.38	A. Müller, Journal für praktische Chemie, 1849, **47.** 340, 342.
	Leaves		Dried at 100°	6.45		17.48	29.58	3.00	
	Fruit		Air dried	2.61		43.12	20.19	6.85	
ORANGE (*Citrus aurantium*)	Wood				9.60	5.64 *	38.90	0.74	4. Berthier.
	Stem			2.74		9.69	16.77	14.17	Rowney and How, Phil. Mag., 1847, **31.** 275.
	Leaves			13.73		12.67	23.32	2.52	
	Seeds			3.30		35.26	12.60	20.36	
	Root			4.48		12.47	19.57	10.86	
	Fruit			3.94		28.26	21.95	8.59	
	Entire fruit					32.61	17.84	12.77	17. Richardson.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* K_2O and Na_2O.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
PALMS	Palm-nut cake of commerce		Air dried	3.00 or 4.00					Vœlcker (and several other observers). See Hoffmann's Jahresbericht for 1865, 1866, 1868, 1870
(*Carypha Pumos*)*.	Wood				56.85	15.28	19.36	3.10	H. Fritsch, American Journal Pharmacy, 1860, **32.** 213.
(*Phytheléphas macrocarpa*) Tagua-nut or vegetable ivory	Nut			0.61					Connell, Phil. Mag., Feb., 1844.
PEACH (*Amygdalus Persica*)	Fruit		Fresh	0.61					11. Margold.
	Entire fruit		Fresh	0.46 1.08					18. Fresenius's pupils.
PEAR (*Pyrus communis*)	Wood				20.00		30.32	4.00	3. Gueymard.
	Entire fruit		Fresh	0.41		44.89	16.97	12.63	17. Richardson.
	do.		Fresh	0.34 0.33					18. Fresenius's pupils.
	do.		Fresh	0.38 0.37					11. Margold.
(*Pyrus Amelanchier* or *Amelanchier vulgaris*), a European plant allied to the American Shad-bush	Wood with its bark		Dried at 100°	3.64		2.71	37.41	2.46	23. Hruschauer.
(*Pyrus aria*) Beam tree	do.		Dried at 100°	1.61		6.77	33.99	5.57	
PERUVIAN BARK (from various species of *Cinchona*):—									
(*China rubra*)	Bark		Dried at 100°	1.66		18.56	33.66	4.94	Reichardt, Jahresbericht, **8.** 720.
(*C. huanuco*)	do.		Dried at 100°	2.51		21.80	32.21	6.10	
Carthagena Bark (*C. flava fibrosa*)	do.		Dried at 100°	1.63		21.69	35.91	3.21	
Calisaya Bark (*C. regia*)	Without epidermis.		Dried at 100°	1.22		21.43	31.74	7.65	
	With epidermis		Dried at 100°	1.65		24.53	24.95	13.58	
Petalostigma quadriloculare	Bark of bodywood			8.30		2.75	40.33	0.56	Falco, Jahresbericht, **19.** 709.

* A kind of Palm growing in Surinam to height of from 40 to 60 feet. Its ashes are used by the natives of that country as a source of common salt. Fritsch found 26.74% of chloride of sodium in the sample of ashes here referred to.

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	
PINE — *continued.*									
Dwarf Pine (*Pinus pumilio*)	Body-wood	. . . .	Dried at 100°	0.28	. . . .	7.64	23.78	3.14	Wittstein, Jahresbericht, 15. [511
	do.	. . . .	. . . .	. . . .	. . . .	15.75	25.25	8.87	7. Johnson and Sendtner.
	do.	. . . .	. . . .	. . . .	. . . .	less than 16.33	28.75	4.05	
	Bark	. . . .	Dried at 100°	1.38	. . . .	3.40	35.72	1.79	Wittstein, Jahresbericht, 15. 511.
(*Pinus Mughus*)	Wood	. . . .	. . . .	. . . .	. . . .	less than 23.71	27.80	5.61	7. Johnson and Sendtner.
Stone Pine (*Pinus pinea*)	Fruit	. . . .	. . . .	4.14	. . . .	. . . .	. . . .	. . . .	Payen, Jahresbericht, 18. 632.
Austrian Pine (?)	Small branches	Autumn?	Dry	1.19	4.69	. . . .	?	4.51	12. Gueymard.
Fossil wood of *Pinites succinifer*	. . . .	. . . .	. . . .	4.96	. . . .	4.04	3.22	15.30	Reinsch, Jahresbericht, 1. 1096.
Fossil cones of ?	. . . .	. . . .	. . . .	5.22	. . . .	5.22	1.10	17.74	
PLANE TREE	Leaves, fallen of	Autumn	Dry	5.54	18.05	. . . .	?	1.43	12. Gueymard.
PLUM (*Prunus domestica*). [Compare Apricot]	Wood	. . . .	. . . .	. . . .	7.50	. . . .	37.10	2.00	3. Gueymard.
	Entire fruit (Greengage)	. . . .	Fresh	0.40	. . . .	44.06	25.98	11.67	17. Richardson.
	Entire fruit	. . . .	Fresh	0.63	. . . .	. . . .	. . . .	. . . .	11. Margold.
	Entire fruit (several varieties)	. . . .	Fresh	0.65 0.36 0.44 0.54 0.62 0.83 0.66	. . . .	. . . .	. . . .	. . . .	18. Fresenius's pupils.
	Flesh of fruit (Orleans plum)	. . . .	Fresh	0.31	. . . .	43.67	26.40	11.56	17. Richardson.
	Skin of fruit, do.	. . . .	Fresh	0.89	. . . .	47.93	16.92	11.49	
	Kernels of stone, do.	. . . .	Fresh	1.64	. . . .	24.26	4.11	32.24	
	Shell of stone, do.	. . . .	Fresh	0.24	. . . .	19.50	13.30	24.93	
Perfumed Plum (*Prunus Mahaleb*)	Branches of medium size	. . . .	Air dried	1.60	16.00	10.08 *	28.79	4.92	4. Berthier.
	Bark	. . . .	Dried at 100°	11.20	. . . .	6.79	39.19	0.20	Kittel, Jahresbericht, 11. 525.
Sloe, or Blackthorn (*Prunus spinosa*)	Fruit	. . . .	. . . .	2.08	. . . .	34.80	?	10.50	Schreiner in Liebig's Agrikultur Chemie, p. 349.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* K_2O and Na_2O.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
POMEGRANATE (*Punica granatum*)	Bark of root		Dried at 100°	12.02		4.75	38.93	2.12	Spiess, Hoffmann's Jahresbericht, 3. 59.
POPLAR, Black, of Europe (*Populus nigra*)	Wood			1.31	6.82				1. v. Werneck.
	do.			1.20	5.83				10. Leuchs.
	Branches, 1½ to 2 c.m. thick, with their bark	Feb.			15.00	16.90	00.00	11.00	13. Malaguti and Durocher.
	Body-wood 8″ thick, without bark		Dried at 25°	0.80	26.00				45. De Saussure.
	Bark from stems 8″ thick		Dried at 25°	7.20	6.00				45. De Saussure.
	Leaves	26 May	Dried at 25°	6 60	36.00				45. De Saussure.
	do.	26 May	Fresh	2.30					45. De Saussure.
	do.	12 Sept.	Dried at 25°	9.30	26.00				45. De Saussure.
	do.	12 Sept.	Fresh	4.10					45. De Saussure.
POPLAR, White, of Europe (*Populus alba*)	Branches, 1½ to 2 c.m. thick, with their bark	Feb.			20.50	18.00	00.00	15.20	13. Malaguti and Durocher.
POPLAR, Lombardy (*P. dilatata*)	Leaves	August	Air dried	9.22					60. Sprengel.
	Wood				11.30		36.10	3.55	3. Gueymard.
	Leaves, fallen of	Autumn	Dry	9.75	4.10		?	3.08	12. Gueymard.
Aspen, of Europe (*Populus tremula*).	Wood		Dry	1.24	6.07				53. Régie.
	do.		Dry	1.73 (Mean of 59 expts.)					30. Chevandier.
	Body-wood and large branches from tree 25 years old		Dried at 140°	1.86					31. Chevandier.
	Wood			1.35	7.41				40. Hohenstein.
	do.				8.50				19. Simon.
	do.		Dry	1.02	8.82				52. Leipzig œk. Gess.
	Body-wood, sound		Dry	4.00	22.00				16. Pissis.
	Body-wood, rotten		Dry	8.00	22.00				16. Pissis.
	Fagots of branches frm trees 25 years old		Dried at 140°	2.98					31. Chevandier.
	Branches 1½ to 2 c m. thick, with their bark	Feb.			7.00	13.44	00.00	13.30	13. Malaguti and Durocher.
	Leaves & tips of twigs	29 July	Dried at 100°	5.02					61. Stoeckhardt.
	Leaves		Dry	4.00					Hoffmann, in his Jahresbericht, 1863, 6. 47.
	Roots		Dry	1.10	10.81				52. Leipzig œk. Gess.

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
POPLAR — *continued.* (*P. fastigiata*)	Branches, 1½ to 2 c.m. thick, with their bark	Feb.	. . .	. . .	10.54	10.17	00.00	11.52	13. Malaguti and Durocher.
(*P. Virginiana*)	do.	Feb.	. . .	. . .	11.00	11.32	00.00	14.47	13. Malaguti and Durocher.
Quillaja saponaria (Soap-bark of So. America)	Internal layer of bark	. . .	Air dried	13.94	. . .	. . .	. . .	. . .	Bleekrode, cited in American Journal Pharmacy, 1860, **32.** 241.
	do.	. . .	Dried at 100°	18.50					
QUINCE (*Cydonia vulgaris*)	Seeds	. . .	. . .	. . .	. . .	27.09	00.00	42.02	43. Souchay.
RASPBERRY (*Rubus Idæus*)	Sticks, ½ to 1½ c.m. thick with their bark	Feb.	. . .	. . .	13.07	14.23	00.00	23.61	13. Malaguti and Durocher.
	Fruit	. . .	Fresh	0.40 0.78 0.46	. . .	. . .	. . .	. . .	18. Fresenius's pupils.
	do.	. . .	Fresh	0.33	. . .	. . .	. . .	. . .	11. Margold.
Rhododendron ferrugineum	Stems and branches	20 June.	Dried at 25°	0.80	22.50	. . .	. . .	. . .	45. De Saussure.
	Ditto, from another locality	27 June.	Dried at 25°	0.80	24.00				
	Leaves	20 June.	Dried at 25°	3.00	23.00				
	Ditto, from another locality	27 June.	Dried at 25°	2.50	21.10				
ROSE, "Wood rose" (*Rosa canina*)	Stems, ½ to 1½ c.m. thick with their bark	March	. . .	. . .	25.20	19.16	00.00	16.10	13. Malaguti and Durocher.
	Stems	. . .	. . .	0.62	8.00	. . .	. . .	. . .	40. Hohenstein.
Rottlera Schimperi (Musena Bark)	Bark	. . .	. . .	5.50	. . .	. . .	. . .	. . .	Thiel, cited in American Journal Pharmacy, 1863, **35.** 324.
Samadera indica	Bark	. . .	Air dried	7.93	. . .	. . .	. . .	. . .	Rost van Tonningen, cited in American Journal of Pharmacy, 1859, **31.** 342.
	Fruit	. . .	Air dried	2.73					

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SAPAN-WOOD (*Cæsalpinia Sapan*)	Wood		Dried at 100°	0.85		3.21	38.91	2.23	Kœchlin, Annalen Chemie und Pharmacie, 1845, **54**. 344.
SERVICE-TREE, wild. See under Hawthorn									
SLOE See Plum.									
Spirea ulmaria	Entire plant	July			29.00	16.31	00.00	12.76	13. Malaguti and Durocher.
SPRUCE, common of Europe. "Norway Spruce" (*Abies communis*)	Wood			1.68	12.28				1. v. Werneck.
	do.		Dry	1.02 (mean of 46 expts.)					30. Chevandier.
	Wood from stem of tree 90 to 100 years old	May	Dry	0.41					29. Schroeder, pp. 199, 202.
	Ditto, from top of do.	May	Dry	0.64					
	Wood, bark, & needles, *i.e.*, the entire tree	May	Dry	0.71					
	Wood		Dry	0.34					53. Régie.
	do.		Dry	0.34	13.20				27. Kirwan.
	do.		Fresh	0.37	13.68	9.30			Lampadius, cited by (25) John, p. 113.
	do.		Fresh	0.31					
	do.				13.20				19. Simon.
	do.				10.00				59. Uhden.
	Wood, without bark, from trees 90 to 100 years old, taken from stems at height of 4 to 5 ft. from ground	Jan.	Dry	0.222					29. Schroeder.
	do.	Feb.	Dry	0.239					
	do.	March	Dry	0.220					
	do.	April	Dry	0.249					
	do.	May	Dry	0.232					
	do.	June.	Dry	0.235					
	do.	July	Dry	0.225					
	do.	August	Dry	0.224					
	do.	Sept.	Dry	0 249					
	do.	Oct.	Dry	0.217					
	do.	Nov.	Dry	0.269					
	do.	Dec.	Dry	0.230					
	do.	Mean of the year	Dry	0.234		17.27	00.00	1.91	

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
POPLAR — *continued.* (*P. fastigiata*)	Branches, 1½ to 2 c.m. thick, with their bark	Feb.	. . .	. . .	10.54	10.17	00.00	11.52	13. Malaguti and Durocher.
(*P. Virginiana*)	do.	Feb.	. . .	. . .	11.00	11.32	00.00	14.47	13. Malaguti and Durocher.
Quillaja saponaria (Soap-bark of So. America)	Internal layer of bark	. . .	Air dried	13.94	. . .	. . .	. . .	. . .	Bleekrode, cited in American Journal Pharmacy, 1860, **32.** 241.
	do.	. . .	Dried at 100°	18.50					
QUINCE (*Cydonia vulgaris*)	Seeds	. . .	. . .	. . .	. . .	27.09	00.00	42.02	43. Souchay.
RASPBERRY (*Rubus Idæus*)	Sticks, ½ to 1½ c.m. thick with their bark	Feb.	. . .	. . .	13.07	14.23	00.00	23.61	13. Malaguti and Durocher.
	Fruit	. . .	Fresh	0.40 0.78 0.46	. . .	. . .	. . .	. . .	18. Fresenius's pupils.
	do.	. . .	Fresh	0.33	. . .	. . .	. . .	. . .	11. Margold.
Rhododendron ferrugineum	Stems and branches	20 June.	Dried at 25°	0.80	22.50	. . .	. . .	. . .	45. De Saussure.
	Ditto, from another locality	27 June.	Dried at 25°	0.80	24.00				
	Leaves	20 June.	Dried at 25°	3.00	23.00				
	Ditto, from another locality	27 June.	Dried at 25°	2.50	21.10				
ROSE, "Wood rose" (*Rosa canina*)	Stems, ½ to 1½ c.m. thick with their bark	March	. . .	. . .	25.20	19.16	00.00	16.10	13. Malaguti and Durocher.
	Stems	. . .	. . .	0.62	8.00	. . .	. . .	. . .	40. Hohenstein.
Rottlera Schimperi (Musena Bark)	Bark	. . .	. . .	5.50	. . .	. . .	. . .	. . .	Thiel, cited in American Journal Pharmacy, 1863, **35.** 324.
Samadera indica	Bark	. . .	Air dried	7.93	. . .	. . .	. . .	. . .	Rost van Tonningen, cited in American Journal of Pharmacy, 1859, **31.** 342.
	Fruit	. . .	Air dried	2.73					
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SAPAN-WOOD (*Cæsalpinia Sapan*)	Wood		Dried at 100°	0.85		3.21	38.91	2.23	Kœchlin, Annalen Chemie und Pharmacie, 1845, 54. 344.
SERVICE-TREE, wild. See under Hawthorn									
SLOE See Plum.									
Spirea ulmaria	Entire plant	July			29.00	16.31	00.00	12.76	13. Malaguti and Durocher.
SPRUCE, common of Europe. "Norway Spruce" (*Abies communis*)	Wood			1.68	12.28				1. v. Werneck.
	do.		Dry	1.02 (mean of 46 expts.)					30. Chevandier.
	Wood from stem of tree 90 to 100 years old	May	Dry	0.41					
	Ditto, from top of do.	May	Dry	0.64					29. Schroeder, pp. 199, 202.
	Wood, bark, & needles, *i.e.*, the entire tree	May	Dry	0.71					
	Wood		Dry	0.34					53. Régie.
	do.		Dry	0.34	13.20				27. Kirwan.
	do.		Fresh	0.37	13.68	9.30			Lampadius, cited by (25) John, p. 113.
	do.		Fresh	0.31					
	do.				13.20				19. Simon.
	do.				10.00				59. Uhden.
	Wood, without bark, from trees 90 to 100 years old, taken from stems at height of 4 to 5 ft. from ground	Jan.	Dry	0.222					
	do.	Feb.	Dry	0.239					
	do.	March	Dry	0.220					
	do.	April	Dry	0.249					
	do.	May	Dry	0.232					
	do.	June.	Dry	0.235					
	do.	July	Dry	0.225					29. Schroeder.
	do.	August	Dry	0.224					
	do.	Sept.	Dry	0.249					
	do.	Oct.	Dry	0.217					
	do.	Nov.	Dry	0.269					
	do.	Dec.	Dry	0.230					
	do.	Mean of the year	Dry	0.234		17.27	00.00	1.91	

Name of the plant.	Part of the plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of				Observer.
					"Soluble salts."	Real Potash. K_2O.	Carbonic Acid, &c.	Phosphoric Acid. P_2O_5.	
SPRUCE — *continued* .	Wood without bark, from top of the tree, 17.8 metre fm ground	May	Dry	0.30	. . . .	17.18	00.00	4.10	29. Schroeder.
	Wood without bark	. . . .	Dried at 110°	0.31	. . . .	. . . .	. . . .	. . . .	Wunder, Versuchs-Stationen, 1864, **6**. pp. 10, 13.
	Ditto, that had been rafted	. . . .	Dried at 110°	0.46	. . . .	. . . .	. . . .	. . . .	
	Sawdust	. . . .	Dried at 110° to 120°	0.39	. . . .	. . . .	. . . .	. . . .	
	do.	. . . .	Dried at 60°	0.40	. . . .	. . . .	. . . .	. . . .	4. Berthier, Voie sèche, p. 257.
	Wood from a tree 40 to 50 years old	. . . .	. . . .	. . . .	25.70	16.81 *	?	2.21	4. Berthier.
	Planks from Norway	. . . .	Air dried	0.83	50.00	14.10 †	24.93	0.71	
	Medium sized branches	. . . .	. . . .	. . . .	16.70	10.71 *	33.63	3.43	
	Branch's without leaves	20 June	Dried at 25°	1.50	15.00	. . . .	. . . .	. . . .	45. De Saussure.
	Branches, 1½ to 2 c.m. thick, with their bark	March	. . . .	. . . .	17.20	12.84	00.00	2.60	13. Malaguti and Durocher.
	Branches more than 1 c.m. thick, without bark	May	Dry	0.39	. . . .	16.14	00.00	1.66	29. Schroeder. The trees were from 90 to 100 years old.
	Branches more than 1 c.m. thick, with their bark	May	Dry	1.18	. . . .	. . . .	. . . .	. . . .	
	Small branches, less than 1 c.m. thick with their bark	May	Dry	2.01	. . . .	16.83	00.00	8.58	
	Bark of stem, breast high	. . . .	Dry	1.75	. . . .	6.68	00.00	3.40	
	Bark of top, 17.8 metres from ground	. . . .	Dry	2.12	. . . .	18.08	00.00	5.50	
	Bark of branches more than 1 c m. thick	. . . .	Dry	3.45	. . . .	9.90	00.00	3.82	
	Needles	May	Dry	3.82	. . . .	11.37	00.00	9.32	
	Needles	. . . .	. . . .	. . . .	. . . .	"Much"	. . . .	. . . .	25. John, pp. 59 and 148 note.
	do.	. . . .	. . . .	. . . .	. . . .	1.98	8.22 and much SiO_2	0.54	Karmrodt, Hoffmann's Jahresbericht, **7**. 98. [K.'s results are incomprehensible.]
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* K_2O and Na_2O.

† And 20.75% of Na_2O. Wittstein also, as cited in Liebig's Agricultur Chemie, found in one instance 26.80% of soda.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SPRUCE — *continued*	Needles	20 June.	Dried at 25°	2.90	16.00				45. De Saussure.
	Needles from another locality	27 June.	Dried at 25°	2.90	15.00				
	Needles from a young tree			6.25	12.70			Not a large amount	34. Hertwig.
	Needles from a tree 45 years old	Autumn	Dried at 100°	7.13		1.17	18.40	6.75	39. Krutsch.
	Cones					"Very much"			25. John, p. 148 note.
	Roots				25.63				10. Leuchs.
SPURGE LAUREL (*Daphne mezereum*)	Bark		Dried at 110°	4.02		14.23	28.82	5.80	Hoyer, Jahresbericht, **17.** 608.
SUMACH (*Rhus coriaria*) "*Bois noir*" of Berthier	Wood		Air dried	1.49	15.00		?	1.53	4. Berthier.
	do.			1.70	14.70				40. Hohenstein.
(*Rhus toxicodendron*) Poison Ivy	Leaves		Dried at 100°	7.91		25.81	18.43	11.57	Kittel, Jahresbericht, **11.** 530.
TEA (*Camellia bohea, &c.*)	Leaves (genuine)		Air dried of commerce	5.00 to 6.00					Warrington (and others), Jahresbericht, **4.** 717.
THORN. See Hawthorn.									
VIBURNUM. See Wayfaring Tree.									
WALNUT, of Europe (*Juglans regia*)	Wood				31.60		27.80	3.70	3. Gueymard.
	do.				14.96				19. Simon.
	do.				14.00				10. Leuchs, citing Lambert.
	Branches and twigs *				15.02				19. Simon.
	Wood of 1 year old shoots	31 May	Dried at 100°	10.03		42.74	00.00	14.89	56. Staffel.
	do.	27 Aug.	Dried at 100°	2.99		15.29	00.00	12.21	
	Bark	31 May	Dried at 100°	8.75		45.75	00.00	19.94	
	do.	27 Aug.	Dried at 100°	6 40		11.63	00.00	5.85	
	Selected leaves	31 May	Dried at 100°	7.72		42.70	00.00	21.12	
	do.	27 Aug	Dried at 100°	7.01		26.57	00.00	4.04	
	Twigs of a young tree.		Dry	3.82	11.36		?	3.53	12. Gueymard.
	Leaves, fallen of	Autumn	Dry	12 17	12.41		?	1.63	

Name of the plant.	Part of plant examined.	When gathered.	Condition of dryness.	Per cent of ash.	In 100 parts of the ashes there were found parts of "Soluble salts."	Real Potash. K_2O.	Carbonic acid, &c.	Phosphoric Acid. P_2O_5.	Observer.
WALNUT—*continued.*	Root				9.88				19. Simon.
	Nut			0.67		27.12	2.93 *	35.61	Glasson, Annalen Chemie und Pharmacie, 1847, **61.** 343.
	Kernel					30.65	1.63	43.32	17. Richardson.
	Shells					20.94	9.82	5.22	17. Richardson.
	do.		Dry	0.73	3.97		?	0.16	12. Gueymard.
	Nut-cake		Air dried	5.01		30.68	7.57	40.44	Fresenius, Versuchs-Stationen, 1859, **1.** 92.
WAYFARING TREE (*Viburnum lantana*)	Entire plant	Oct.	½ dry	5.31					54. Pertuis.
	Wood			1.85	8.11				40. Hohenstein.
Guelder Rose (*Viburnum opulus*)	Wood			1.60	6.25				40. Hohenstein.
WHORTLEBERRY, or Bilberry of Europe (*Vaccinium myrtillus*)	Fruit		Fresh	0.63					11. Margold.
	do.		Fresh	1.41					18. Fresenius's pupils.
WILLOW, common of Europe (*Salix alba*)	Body-wood		Dry	2.85					53. Régie.
	do.		Dry	2.80	10.20				27. Kirwan.
	do.		Dry	1.03	12.70				52 Leipzig œk. Gess.
	do.			2.80	11.03				1. v. Werneck.
	do.			2.85	12.28				40. Hohenstein.
	do.				15.00		35.01	3.40	3. Gueymard.
	Wood		Dry	2.00 (Mean of 17 expts.)					30. Chevandier.
	Wood of twigs from a tree 20 years old		Dried at 140°	3.67					31. Chevandier.
	Fagots from a tree 20 years old		Dried at 140°	4.57					31. Chevandier.
	Rotten sap-wood, free from bark			2.50	28.57 †				25. John, p. 142.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

* After subtracting sand and coal.

† "It is well-known that sound Willow wood yields very little potash."—John.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
WILLOW—*continued*. Gray Willow (*Salix cinerea*)	Roots	. . . .	Dry	0.97	12.75	. . . .	. . . .	. . . .	52. Leipzig œk. Gess.
	Branches, ½ to 2 c.m. thick, with their bark	March	. . . .	. . . .	16.00	11.37	00.00	16.35	13. Malaguti and Durocher.
Yellow-branched Willow (*Salix vitellina*)	Wood	. . . .	. . . .	. . . .	10.18	. . . .	. . . .	. . . .	19. Simon.
	Branches, 1 year old, with their bark	17 Sept.	Green	0.58	37.84	34.04	1.15 *	13.00	Reichardt, Jahresbericht, 6. 582 and 584.
	Twigs with their bark	22 June.	Green	0.16	50.36	31.96	1.63 *	23.44	
	Leaves	22 June.	Green	0.67	51.06	34.65	1.89 *	12.41	
	do.	17 Sept.	Green	0.71	47.76	40.88	3.28 *	10.23	
	Lower thick bark of a tree 5 years old	Oct.	Dry	6.55	22.12	8.45	Much CO_2	3.48	
	Upper thin bark of a tree 5 years old	Oct.	Dry	7.79	31.42	9.75	Much CO_2	3.43	
	Leaves	August.	Air dried	8.23	. . . .	. . . .	. . . .	. . . .	60. Sprengel.
Great Round-leaved Willow (*Salix caprea*)	Leaves & tips of twigs	29 July.	Dried at 100°	6.48	. . . .	. . . .	. . . .	. . . .	61. Stœckhardt.
"Black Willow" of Denmark	Body-wood	. . . .	. . . .	. . . .	26.25	. . . .	. . . .	. . . .	59. Uhden.
Weeping Willow (*Salix babylonica*)	Leaves, fallen of	Autumn	Dry	10.26	14.81	. . . .	?	2.75	12. Gueymard.
	Leaves	21 Aug.	Dry	8.71	41.85	. . . .	?	8.31	
	Year old twigs, from which the leaves were taken	21 Aug.	Dry	6.75	36.29	. . . .	?	7.76	

* "Sand." The Carbonic Acid has been subtracted in each instance, even from the "matter soluble in water."

[For "REFERENCE LIST OF AUTHORITIES CITED IN THIS TABLE," see next page.

REFERENCE LIST OF THE AUTHORITIES CITED IN THE LARGE TABLE.

1. von Werneck, cited by Hartig in his Forstliches Lexicon, Berlin, 1834, p. 641. [v. Werneck's original paper is in Hermbstædt's Archiv der Agrikultur-Chemie, Berlin, 1812, **6**. p. 62 or 92.]
2. Henneberg's Journal für Landwirthschaft.
3. Gueymard, Comptes Rendus, 1863, **56**. 772. Besides his own determinations, Gueymard has given in this place, with due credit, a number of Berthier's results, and a few that have been obtained by other observers.
4. Berthier, Annales de Chimie et de Physique, 1826, **32**. 248, and further, his Traité des Essais par la voie sèche, Paris, 1834, **1**. p. 259, *et seq*.
5. Sprengel, Erdmann's Journal für tech. und œk. Chemie, 1832, **13**. pp. 384, 389; and Journal für praktische Chemie, 1834, **1**. 159.
6. Sprengel, C., in his Chemie für Landwirthe, Göttingen 1832, **2**. 384, *et seq*. Only the ash determinations of Sprengel have been cited. His *analyses* of the ashes are known to be untrustworthy.
7. Johnson and Sendtner, Annalen der Chemie und Pharmacie, 1855, **95**. 234–241.
8. Röthe, Bericht der Naturhistorischen Vereins in Augsburg, 1856, **9**. 29.
9. Zedeler, Annalen der Chemie und Pharmacie, 1851, **78**. 351.
10. Cited by Leuchs, E. F., in his Der potaschen-Fabrikant, Nürnberg 2te Auflage, 1844, pp. 15–18. According to Leuchs, his figures depend upon the results of Wiegleb, Kirwan, Wildenhayn, J. C. Leuchs, Rœsig, and other observers. The same figures are given by Hermann, H. G., in his Praktische Anweisung zur Bereitung der Potasche, Quedlinburg and Leipzig, 1835, p. 3. as "taken from the statements of various authors;" and many of them by Chevallier, in Dingler's polytech. Journal, 1833, **48**. 380, who states that the figures of his tables are arithmetical means obtained from the results of Kirwan, Vauquelin and Pertuis. They have been repeated by (40) Hohenstein also.
11. Margold, Knop's Lehrbuch der Agricultur-Chemie, 1868, **1**. 714.
12. Gueymard, Comptes Rendus, 1864, **59**. 992. In this memoir G. reports "phosphates of lime and iron." I have taken 46% of his figures indicating these mixed phosphates, in order to obtain the approximative estimates of phosphoric acid that are given in the table.
13. Malaguti and Durocher, Annales de Chimie et de Physique, 1858, **54**. 257.
14. Fresenius and Will, Annalen der Chemie und Pharmacie, 1844, **50**. 393.
15. C. Erdmann, Annalen der Chemie und Pharmacie, 1855, **94**. 255.
16. Pissis, Annales de Chimie, 1801, **38**. 91.
17. Richardson, Annalen der Chemie und Pharmacie, 1848, **67**. 377.
18. Fresenius's pupils, Annalen der Chemie und Pharmacie, 1857, **101** pp. 225–231.
19. Simon, C. F. W., Die Fabrikation der russichen Pottasche in Deutschland. Quedlinburg and Leipzig 1845, p. 6. According to Simon, his results are the arithmetical means of repeated original trials with the several kinds of wood. A large quantity of the wood to be tested was used as fuel to feed the calcining furnaces at his works. The ashes obtained were strongly ignited, and then leached by themselves.
20. Brix, cited by Kerl B., in his Handbuch der Hüttenkunde, Freiberg, 1861, **1**. 247.
21. Zeyer, Liebig and Kopp's Jahresbericht, **14**. 771.
22. Hambright, American Journal of Pharmacy, 1863, **35**. 200.
23. Hruschauer, Annalen der Chemie und Pharmacie, 1846, **59**. pp. 201–206.
24. Wiegleb, cited by John in his Ernährung der Pflanzen, pp. 23, 24.
25. John, J. F., in his work Ueber die Ernährung der Pflanzen, Berlin, 1819, pp. 59, 60, 65, 139–142.
26. Sprengel, Erdmann's Journ. tech. und œk. Chemie, 1829, **5**. 135, 292.
27. Kirwan, Transactions Royal Irish Academy, 1789, **3**. pp. 35, 36. Most of the figures in Kirwan's memoir seem to have been derived from a pamphlet published in France by the Administration of powder and saltpetre. I have omitted those that were manifestly duplications of (53) Pertuis's citations.
28. Wicke, Henneberg's Journal für Landwirthschaft, 1862, **7**. 143, *et seq*.

29. J. Schrœder, Stœckhardt's Chemische Ackersmann, 1873, **19.** 198.
30. Chevandier, Comptes Rendus, 1847, **24.** 269.
31. Chevandier, Annales de Chimie et de Physique, 1844, pp. 137–148.
32. Handtke, Stœckhardt's Chemische Ackersmann, 1863. **9.** 249.
33. Wunder, Die landwirthschaftlichen Versuchs-Stationen, 1864, **6.** 10.
34. Hertwig, Annalen der Chemie und Pharmacie, 1843, **46.** 102.
35. Heyer, Annalen der Chemie und Pharmacie, 1852, **82.** 185.
36. Böttinger, Annalen der Chemie und Pharmacie, 1844, **50.** 407.
37. Witting, Liebig and Kopp's Jahresbericht, **4.** 712.
38. Wittstein, Liebig and Kopp's Jahresbericht, **15.** 510.
39. Krutsch, Stœckhardt's Chemische Ackersmann, 1863, **9.** 22.
40. Cited by Hohenstein, A., in his Die Pottaschen-Fabrikation, Wien, 1856, p. 18, *et seq.* [I have copied nothing from this work excepting certain results which purport to depend upon independent observations. It will be noticed, however, that many of the figures taken from Hohenstein are remarkably similar to those of v. Werneck.]
41. Zoller, Die landwirthschaftlichen Versuchs-Stationen, 1864, **6.** 231.
42 F. Schulze, in his Chemie für Landwirthe, Leipzig, 1853, **2.** pp. 75, 80.
43. Souchay, Annalen der Chemie und Pharmacie, 1845, **54.** 348.
44. Brandl and Rackowiecki, Liebig and Kopp's Jahresbericht, **17.** 607.
45. De Saussure, in his Recherches Chimiques, Paris, 1804.
46. Schütze, cited in Stœckhardt's Chemische Ackersmann, 1873, **19.** 200.
47. Engelmann, Annalen der Chemie und Pharmacie, 1845, **54.** 342.
48. Levi, Annalen der Chemie und Pharmacie, 1844, **50.** 423.
49. Vogel, Annalen der Chemie und Pharmacie, 1844, **51.** pp. 140–143.
50. Wrightson, Annalen der Chemie und Pharmacie, 1845, **54.** 341.
51. Sacc, Annales de Chimie et de Physique, 1849, **25.** 224.
52. Experiments of the Leipzig ökonomische Gesellschaft, cited by (40) Hohenstein, p. 33.
53. Régie [French Administration of powder and saltpetre], cited by Pertuis, Annales de Chimie, 1797, **19.** 162.
54. Pertuis's own observations, Annales de Chimie, 1797, **19.** 162. According to Pertuis, his woods were "burnt with great care."
55. Wolff, Journal für praktische Chemie, 1848, **44.** 385.
56. Staffel, Annalen der Chemie und Pharmacie, 1850, **76.** 379; and further, Liebig and Kopp's Jahresbericht, **3.** p. 661 and Table D. [The woods examined by Staffel were carbonized, after H. Rose, and the ashes seem to have been carefully analyzed.]
57. L. Hoffmann, Annalen der Chemie und Pharmacie, 1845, **56.** 125.
58. Herapath, Journal London Chemical Society, 1849, **1.** pp. 104–115.
59. Uhden, cited by (40) Hohenstein, p. 34.
60. Sprengel, Erdmann's Journ. tech. und œk. Chemie, 1830, **7.** 267; and **8.** pp. 11 and 269.
61. Stœckhardt, in his Chemische Ackersmann, 1866, **12.** 51.

It is interesting to recall the fact that, nearly a hundred years ago, the French Administration of Powder and Saltpetre * of those days, reported as the result of their experiments upon four kinds of wood, — viz., oak, beech, hornbeam, and aspen, — that the mean product of ash was 1.08%, and the amount of crude potashes in the ash 11.59%.

Much more recently, another French observer, Chevandier,† has reported as the result of a very large number of experiments (524 in all), made expressly for the purpose of obtaining trustworthy data, that the average yield of ashes from nine kinds of wood (viz., willow, aspen, oak,

* Cited by Pertuis, "Annales de Chimie," 1797, **19.** 162. According to Kirwan, the woods in question were "burnt in a clean chimney and open fire."

† "Comptes Rendus," 1847, **24.** pp. 269, 274.

hornbeam, alder beech, pine, spruce, and birch), taken altogether, and with the bark that belongs to each part, is for the

Stems of very young trees	1.23%	of the dry wood
Split wood from older trees	1.34%	,, ,,
Branches not large enough to need splitting	1.54%	,, ,,
Fagots	2.27%	,, ,,

It would seem, however, that the woods burnt by Chevandier had been very sharply dried before weighing, and that the percentage of ashes above given must consequently be a trifle higher than would have been found by the usual method of estimation. No mention of the temperature at which the woods were dried is made in the article from which the foregoing figures were taken. But in several other memoirs published by Chevandier, he distinctly states his habit of experimenting upon woods that have been dried at 140°(C.) [= 284° F.].

I have purposely omitted to mention in the table a large number of determinations of the percentage amounts of ashes in the charcoal of various kinds of woods that have been made by Violette,* Berthier,† and Karsten.‡ Since the amounts of wood from which these charcoals were produced have been reported in most instances, it would at first sight seem to be an easy matter to calculate from the analytical data the percentages of ash in the original woods. Indeed, a number of results thus obtained by Berthier have been often cited in chemical literature. But the figures computed in this way often differ considerably from those that have been obtained by the direct incineration of wood, and there are grounds for believing that they are less trustworthy than the latter on the whole.

One reason why the determinations made upon charcoal need not be quoted in this connection, depends upon the fact that most of them refer not to ordinary wood that has been burned with the bark natural to it, like wood that is used as fuel, but to wood that has been carefully deprived of its bark, as in the preparation of charcoal for the powder-maker. All of Violette's experiments, some of those of Berthier, and perhaps Karsten's also, were made upon the charcoal of wood from which the bark had been removed, while most of the results given in the table undoubtedly refer to ordinary fire-wood that was burnt with its bark.

It would of course be interesting, from the scientific point of view, to know how much ashes is yielded by barkless woods of various kinds; and it is undoubtedly true that more information upon this point may be got from the researches of Violette, and the other investigators of charcoal, than from any other source. But it does not appear that this informa-

* "Annales de Chimie et de Physique," 1851, **32.** 341, and 1853, **39.** 294.

† "Traité des Essais par la Voie sèche," Paris, 1834, **1.** 249, 260.

‡ Cited in Schubarth's "Handbuch der technischen Chemie," Berlin, 1839, **1.** 291.

tion is strictly correct, or that the details of it can fairly be cited as if they were of the same general order as the results given in the table.

On comparing the percentages of ash, given in the table above, that have been got directly from wood, with the results now in question, that have been obtained from charcoal, it is hard to escape the conviction that the latter do not indicate the whole of the ashes that the woods really contained. It would seem that the absolute amount of ash in charcoal is almost always a little less than the amount of ash in the wood from which the coal was produced.

There was undoubtedly something of truth in the old notion of Neumann, Wenzel, and other of the early chemists,* that wood burnt in the open air yields more "salt" than can be got from the charcoal obtained from a similar amount of wood. Even the opponents † of this view have shown that a certain amount of earthy, non-volatile matters are always lost during the distillation of wood, especially when the distillation is rapid, and the escape of the volatile products tumultuous. Braconnot ‡ found 27½ per cent of ashes in powdery soot from wood smoke, taken from the middle of a chimney, and in lamp-black he found 2% of ash. Violette § goes so far as to assert from the results of his own experience, that "it must be admitted that, in the ordinary processes of carbonization, the matters that separate by volatilization carry off about 3% of mineral matters, either mechanically or in a state of combination with hydrogen." It is to be noted, however, that the experiments upon which Violette ‖ specially bases this conclusion may perhaps have been vitiated by matters derived from the glass tubes in which the trials were made.

The following examples, taken at random, may serve to indicate the difference between the amounts of ash obtained by incinerating charcoal and those obtained directly from wood. On burning the charcoal obtained from 100 parts of wood from birch-trees, 10 or 12 years old, Violette found enough ash to amount to 0.30% of the wood dried at 150°. Berthier ("Voie Sèche," p. 249) found 0.30% of ash by operating on the carbon of air-dried wood; and Karsten got 0.25% and 0.30% accordingly as he operated upon the wood of young or of old trees. But all these numbers are much smaller than those, given in the table above, that have been obtained by the direct incineration of birch-wood.

From the charcoal of the wood of a grape-vine, 10 or 12 years old, Violette got only as much ash as would amount to 0.10% of the wood dried at 150°. But from the table above it appears that 3% or more of ash has usually been met with in dry vine-wood.

* See John's "Ernährung der Pflanzen," Berlin, 1819, p. 8.

† For example, Wiegleb and John. See the latter's "Ernährung der Pflanzen," pp. 23–25, and note.

‡ "Annales de Chimie et de Physique," 1826, **31.** pp. 50, 57.

§ "Annales de Chimie et de Physique," 1851, **32.** 332.

‖ *Loc. cit.* pp. 326–332.

From hornbeam charcoal (from a tree fifteen or twenty years old) Violette got ash to the amount of 0.22% of the wood dried at 150°; Karsten got 0.32% and 0.35% by operating on the charcoal of young wood and old wood respectively.

From horse-chestnut charcoal (from a tree 20 or 30 years old), Violette got ash amounting to 0.33% of the wood.

From oak charcoal (from trees 10 or 12 years old), Violette got ash amounting to 0.09% of the wood; Karsten got 0.11% and 0.15% by operating on the charcoal of old and of young wood respectively; and Berthier * 0.4%.

As has been already intimated, most of these experiments were made upon charcoal from barkless wood, and since bark contains a very much larger proportion of ash than wood does, it is but natural that much less ashes should be found in wood from which the bark had been removed than in that which was burnt together with its bark. But while the absence of bark goes far to explain the small proportion of ashes found in wood by Violette, it does not appear that the differences between his results and those of the generality of observers can be wholly explained in this way. There will be found in the table above given, in several instances, determinations of the amounts of ashes obtained by burning wood by itself, without its bark, that may be compared directly with the results just cited. Thus, for example, Berthier, in his "Voie Sèche," p. 256, found in oak sawdust free from bark, 1.1% of ashes; Sprengel found 0.21, 0.27, and 0.31% of ash in oak heart-wood, and 0.53% in the sap-wood. De Saussure found 0.20% in heart-wood, and 0.40% in sap-wood; and John found 0.67% in heart-wood. So, too, in heart-wood from hornbeam trees, Sprengel found 0.41% of ash, while De Saussure found 0.60% in heart-wood and 0.70% in sap-wood: figures which are notably larger than the 0.22, 0.32, and 0.35 deduced from the experiments upon charcoal, as just now cited.

More evidence of this kind could readily be accumulated by contrasting Violette's estimations of the ash in various other kinds of wood with kindred results in the table. It is true that many of these comparisons will be found to be less precise than could be wished; that sometimes the differences between the experiments of various observers, cited in the table, are as large as the differences between the results obtained by the two methods of incineration now in question; and that, in general, the proportion of ash obtainable in any way from barkless wood, is very much less than would be supposed at first sight on inspecting the figures of the table. Comparatively little is really known either as to the average amounts of ashes contained in wood proper (free from bark) or as to the average difference between ash determinations made upon charcoal and those made directly with wood; and it will hardly be pos-

* "Essais par la Voie Sèche," p. 249. The comparatively high percentage of ash in this case may have been due to some admixture of bark with the wood.

sible to reach any very definite conclusion upon either of these questions except by accumulating a much larger number of direct estimations of the ash in barkless wood than have hitherto been published. For the present, it will be enough to urge that the evidence now existing is on the whole unfavorable to the acceptance of those determinations of the amounts of ashes in wood that have been made by burning charcoal instead of the original wood. An exception to this general conclusion should perhaps be made with respect to the soft resinous woods, like pine and spruce and fir; for the differences between the ash determinations that have been made by different experimenters, operating upon these woods, are but small, no matter what process was employed. Thus, for example, Violette, working with charcoal, got 0.20% of ash in barkless Scotch pine-wood; and Berthier (see his "Voie Sèche," p. 249) got, in a somewhat similar way, 0.40%, in both pine and spruce; while in another pine ("*Pin maritime*") Violette got 0.23% of ash But in barkless spruce-wood, burnt directly, Schrœder got only from 0.22 to 0.30% of ash, and Wunder only from 0.31 to 0.39%.

No. 11. — *On the Importance as Plant-food of the Nitrogen in Vegetable-mould.* By F. H. Storer, Professor of Agricultural Chemistry.

In the course of numerous experiments upon the growth of plants in various kinds of soils, which have been made in the glass-house of the Bussey Laboratory during the last three years, I have been repeatedly impressed by the extreme facility with which plants can obtain from ordinary peat or loam a supply of nitrogen sufficient for their vigorous growth, provided the ash-ingredients necessary to the life of the plant are at hand, that the earth is kept moist, and moderately warm, and that it is in good mechanical condition.

There is, really, little of novelty in the observation, which must have often been made already, in respect to plants grown in flower-pots according to the ordinary methods of domestic life. The fact is exhibited, moreover, in nature, upon a stupendous scale, and is so familiar in one sense that it almost seems idle to discuss it. But it is none the less true, upon the other hand, that the precise significance for practical agriculture of the supplies of nitrogen natural to the soil has never been made clear, and that the discussion of the subject is beset with many doubts and uncertainties that need to be removed. It would seem indeed, at first sight, that the familiar fact that a plant may grow even luxuriantly in a pot of loam to which nothing but rain-water is added, must be inconsistent with another fact equally familiar, — namely, that the fertility of a vast number of soils rich in "humus" is greatly increased by the application of nitrogenous manures, — and be absolutely contradicted by the experiments of Boussingault,* which have hitherto seemed to prove that a fertile garden soil has little if any more power than so much sand to supply plants with nitrogen.

It is because of these seeming contradictions, no doubt, that the power which the organic matters in the soil really possess of supplying

* See his work entitled "Agronomie, Chimie Agricole et Physiologie," Paris, 1860, 1. pp. 283–359. Compare Johnson's "How Crops Feed," New York, 1870, p. 280. The earth used in Boussingault's experiments contained 0.26% of nitrogen.

nitrogen to plants is not very clearly understood, or not allowed for to the extent that it deserves, or sometimes not even recognized.

The experiments to be described directly were neither devised nor carried out with the idea of elucidating the present question, but for a totally different purpose; and it must be said of them, in so far as they may seem to conflict with the analogous experiments of Boussingault, that, as regards matters of analytic detail, they cannot be put in comparison with the research of that observer. Though carefully and faithfully performed, they make no pretence to that elaboration and scrupulous attention to details which would naturally be demanded of any experimenter who might seek to review Boussingault's work. To my mind no such review is needed. Boussingault has given conclusive proof that plants are not nourished to any great extent by soil-nitrogen when supplied in the quantities and exposed to the conditions which obtained in most of his experiments. But it is none the less true of my own experiments, that they have clearly exhibited the power of plants to obtain support from the nitrogen of the soil, under the conditions in which they were performed. The sharp contrasts to be seen in the results of these experiments, accordingly as the nitrogen of peat or loam was or was not present in the pots, is a kind of evidence that cannot be readily discredited or lightly set aside. The simplicity of the method, moreover, makes it easy for any one to perform an experiment for himself which will afford ocular demonstration of the most convincing character. I cannot but feel that the conclusions to which these experiments point have a direct and immediate bearing upon one of the most important problems in practical agriculture.

The following record of results has been taken almost at random from a collection which contains many others of similar import. They are comparable for the most part with those on pages 54 to 70 of this Bulletin. It is to be remarked that in all the experiments I have sought to keep the temperature of the glass-house at from 68° to 70° F. by day, and at 48° to 50° by night. In point of fact the temperature of the house seldom rises above 82° or 83°, and very rarely falls below 44° or 45°, during the season allotted to the experiments. The jars are constantly kept decidedly moist, but not overwet. The comparative ease with which the soil contained in glass jars can be kept really moist, constitutes one of the chief advantages of these vessels for experimental purposes as compared with the ordinary porous earthen flower-pots.

Growth of Buckwheat in a Mixture of Peat and Coal Ashes. — On December 11, 1872, a glass preserve jar was charged with an intimate mixture of 250 grammes of anthracite ashes free from nitrogen, such as were used in the series of experiments recorded on page 54 of this "Bulletin," and 230 grammes of air-dried peat from the Bussey Farm, containing 1.2% of nitrogen, as has been stated on page 135. Three buckwheat seeds were planted in this soil, and the jar was watered with rain-water until March 4, 1873, when the crop was harvested. On December 20, three germinated buckwheat seeds were planted in a second jar that had been charged like the first with a mixture of peat and coal ashes, and the jar was watered with rain-water like the other; but one of the plants was removed on January 2, in order to bring the second jar into close comparison with the first, where only two out of the three seeds that were planted had grown. The results of these experiments are as follows: —

No. of the Jar.	The Crops, harvested March 4, 1873,		
	Weighed in grms. (Dried at 90° to 100° c.)	Grew to height in inches.	Had Seeds.
I. . . .	. . 1.750 . .	. 1 = 20 . . 1 = 15 .	. . 25
II . . .	. . 1.100 . .	. 1 = 18 . . 1 = 12 .	. . 22

The plants had every appearance of being amply supplied with nitrogen. They were in fact remarkably vigorous and succulent, so much so indeed that the stem of one of the plants burst open longitudinally when it was about a month old.

The significance of these results will appear on comparing them with those of the table on page 54. It will there be seen that the two buckwheat plants of jar No. 5, that were reared with rain-water in coal-ashes by itself gave a crop that weighed only a twelfth part as much as the worst of the two crops above described; that they yielded but two seeds instead of twenty-two; and that the crop was in every respect feeble and insignificant. It will be noticed, moreover, that the addition of nitrogenized salts to the coal-ashes enabled them to support crops very much in the same way as was the case when peat was added. Differences such as these, seen in the concrete, as when the

living plants are actually contrasted, carry a conviction to the mind of the observer that is not easily expressed in words.

The peat used in these experiments, and in several of those which follow, was from the same bed as that employed upon Section AA in the field experiments of 1871 and 1872, which were reported in a previous number of this "Bulletin" (pages 80 to 115). In those experiments it did not appear that the application of peat to the land did any good; but the conditions to which the peat was exposed upon the field were necessarily very different from those which obtained in the glass-house; and, moreover, the soil of the field already contained an abundant supply of nitrogenized matters, as the records of crops obtained upon the adjoining section A show.

Growth of Maize in Peat and Coal Ashes. — On January 21, 1873, one glass preserve jar was charged with a mixture of 230 grammes of air-dried peat from the Bussey Farm, and 250 grammes of coal-ashes such as were used for the experiments reported on pages 60 and 69, and which, as it turned out, were not of themselves altogether free from nitrogen; while another jar was filled with the peat alone. Two kernels of common yellow corn were planted in each jar, and the soils were watered with rain-water until April 29, when the crops were harvested with the following results: —

No. of the Jar.	The Crops, harvested April 29, 1873,	
	Weighed in grms. (Dried at 90° to 100° C.)	Grew to height in inches.
I — Peat and Ashes	. . . 5.830 . . .	. . { 1 = 12 1 = 10
II — Peat alone . .	. . . 5.385 . . .	. . { 1 = 10 1 = 8

The color and appearance of the plants were good, and the conviction that they obtained nitrogen from the peat was unavoidable. Compare the table on page 69.

Growth of Buckwheat in Peat, and in Mixtures of Peat with New Jersey Green Sand, Berkshire Sand, and Coal-Ashes (of the sort not wholly free from nitrogen). — On February 13, 1873, four glass preserve jars were filled with the following substances; viz., No. I. with a mixture of 250 grammes of "West Jersey green sand marl" and 230

grammes of the Bussey peat; No. II. with a mixture of 250 grammes of Berkshire sand, and 230 grammes of the Bussey peat; No. III. with a mixture of 250 grammes of coal-ashes, of the kind employed for the experiments that have been described on page 60, and 230 grammes of the Bussey peat; and No. IV. with 350 grammes of the peat by itself. Two buckwheat seeds were planted in each jar, and the several soils were watered with rain-water throughout the experiment. The results of these trials were as follows: —

No. and Contents of the Jar.	The Crops, harvested April 29, 1873,		
	Weighed in grms. (Dried at 90° to 100° c.)	Grew to height in inches.	Had Seeds.
I — Green Sand and Peat .	. . 1.16 . .	. { 1 = 17; 1 = 11 } .	Many flowers, but no mature seeds.
II — Berks. Sand and Peat .	. . 0.47 . .	. . . . 19 .	2 seeds and several flowers. Only 1 plant.
III — Coal Ashes and Peat .	. . 1.83 . .	. { 1 = 24; 1 = 22 } .	9 seeds and many flowers.
IV — Peat alone .	. . 2.71 . .	. { 1 = 23; 1 = 21 } .	21 seeds and many flowers.

These results are comparable to a certain extent with those recorded on pages 60, 63, and 64. See also page 254. It will be noticed, however, that there were fewer plants in each jar in the present case than before. The fact that the mere peat gave the best crop of all, probably depended upon the mechanical condition of that substance. It lay light and porous in the jar, and afforded an easy passage for air and for the roots of the plants.

In the case of the New Jersey green sand, which is a substance naturally well supplied with most of the inorganic constituents of plant food, the need of nitrogen is manifest, and the advantages to be gained by adding it are easily shown, as has been already remarked, on page 65. The following table exhibits this fact anew, and will serve also to illustrate the significance of the nitrogen in peat, as just recorded, when compared with that of the nitrates which were here used in its stead.

A series of nine glass preserve jars were charged with the "West Jersey green sand marl," — 1210 grammes of it being weighed out for each jar. Certain chemicals of the kinds and amounts recorded in the

table were mixed with the green sand; two buckwheat seeds were planted, February 13, 1873, in each jar; and the entire series was watered with rain-water until the crops were harvested. The following results were obtained: —

No. of the Jar.	The jar contained 1210 grms. of the green sand, plus —	The Crops, harvested April 29, 1873,			
		Weighd in grms. (Dried at 90° to 100° C.)	Grew to height in inches.	Had Seeds.	Remarks.
I	0.1 grm. of Nitrate of Ammonia . .	. 1.17 .	{ 1 = 15 1 = 14 }	17	
II	0.1 grm. of Nitrate of Ammonia and 0.5 grm. of Chloride of Potassium	. 0.24 .	. . . 10 .	0	Only 1 plant.
III	0.1 grm. of Nitrate of Ammonia and 0.5 grm. of Phosphate of Soda .	. 1.40 .	. . . 17 .	11	Only 1 plant.
IV	0.1 grm. of Nitrate of Ammonia and 0.5 grm. of Phosphate of Lime .	. 1.83 .	{ 1 = 18 1 = 17 }	7	
V	Nothing	. 0.04 .	. . . 5 .	0	
VI	0.5 grm. of Chloride of Potassium	. 0.04 .	{ 1 = 4 1 = 3 }	0	
VII	0.5 grm. of Phosphate of Soda .	. 0.05 .	{ 1 = 6 1 = 5 }	0	
VIII	0.5 grm. of Phosphate of Lime .	. 0.04 .	{ 1 = 5 1 = 4 }	0	
IX	0.25 grm. of Nitrate of Soda. . . .	. 1.96 .	{ 1 = 16 1 = 14 }	9	

The results obtained in this series of experiments are not quite so high as those reported on page 64, because the method of mixture here used is inferior to the method of watering with saline solutions that was employed in the other case. The experiments tend to show that the nitrates of soda and of lime are useful additions to the green sand. They probably liberate some of its potash, besides supplying nitrogen.

Growth of Buckwheat in Mixtures of Peat or Loam and Berkshire Sand. — The following experiments were made in the winter of 1873–74. Three seeds were sown upon the same day, — November 25, 1873,

— the jars stood side by side, and they were all watered with rain-water throughout the experiment. The glass preserve jars of this set of experiments were charged as follows: —

No. of the Jar.	Contents of the Jar.	The Crops, harvested Feb. 20, 1874,			
		Weighed in grms. (Dried at 90° to 100°C.)	Grew to height in inches.	Had Seeds.	Remarks.
I	500 grms. Loam* from Bussey Plain-field and 700 grms. Berkshire Sand	1.230 .	1 = 13 1 = 11½ 1 = 9	13	
II	500 grms. Loam* from Broadfields Farm and 700 grms. Berkshire Sand	0.765 .	1 = 10½ 1 = 10 1 = 9	8	
III	500 grms. Loam* from Mr. H. Saltonstall's old Pasture and 700 grms. Berkshire Sand . . .	2.480 .	1 = 19 1 = 16 1 = 10	1, and several flowers	The plants were still green and immature when harvested.
IV	250 grms. Peat from Bussey Farm, & 375 grms. Berkshire Sand . . .	1.790 .	2 = 12 1 = 9½	10	
V	300 grms. Peat from Dabney Estate and 450 grms. Berkshire Sand	0.975† .	1 = 17 1 = 12	12	Only 2 plants.
VI	80 grms. Kaolin and 1200 grms. Berkshire Sand	0.100† .	1 = 7 1 = 5½	3½	Only 2 plants.
VII	45 grms. Pipe Clay and 1300 grms. Berkshire Sand	0.060‡ .	1 = 7	1	Only 1 plant.
VIII	Berkshire Sand alone .	0.100† .	1 = 3½ 1 = 3	0	Only 2 plants.

Lest the absolute smallness of the figures in the above table should mislead the reader, it may be remarked that the amount of crop harvested from jar No. 3 was at the rate of some 7,000 lbs. of dry buckwheat straw to the acre of land. This estimate is based upon the fact that the quart of mixed soil in the jar weighed $2\frac{1}{2}+$ lbs., whence the weight of an acre of it taken to the depth of one foot (= 43.560 C. F.) would be about 3,250,000 lbs. The amount of straw harvested from jar No. 8 on the other hand was at the rate of 285 lbs. to the acre.

* In the loam from Bussey Plain-field, dried at 100° C., analysis indicated 0.24% of nitrogen; in that from Broadfields Farm, 0.27%, and in that from Mr. Saltonstall's Pasture, 0.20%.

† Only two plants. ‡ Only one plant.

Compare the results recorded in the table below, where the plants were fed with potash and phosphoric acid.

It has already been shown, on pages 63 and 65, that good crops may be got from the sterile Berkshire sand, by adding to it the various elements of plant-food ; and the same remark is true of the mixtures that contained kaolin and pipe-clay in the present set of experiments. These facts are of course no more than particular instances of the well-known truth, that has often been illustrated, that several kinds of food are needed by plants, and that the absence of either of them is fatal to the life of the plant. But the figures of the last table, on being compared among themselves and with those of the tables on pages 54 to 65, show clearly that the loams and peats of jars Nos. 1 to 5 afforded a very considerable supply of each of the elements of food needed by the plants that were grown upon them.

For the present it concerns us particularly to remark that nitrogen was supplied to the plants in abundance by each of the peats and loams. The significance of this fact will appear even more clearly on

No. of the Jar.	The Jar contained a mixture of Sand (see page 258) and	The Crops			
		Weighed in grms. (Dried at 90° to 100°C.)	Grew to height in inches.	Had Seeds.	Remarks.
I	Plain-field Earth . . .	1.820	2 = 15 1 = 13	22	
II	Loam from Mr. Appleton's Broadfields Farm	1.932	1 = 17 1 = 12 1 = 10	22	
III	Loam from Mr. Saltonstall's Pasture . . .	2.151	3 = 15	7, and many flowers	The plants were very green, and not nearly ripe when harvested.
IV	Bussey Peat	2.190	1 = 14 1 = 13 1 = 12	14	
V	Dabney Peat	1.410*	1 = 12½ 1 = 8½	11, and many flowers	Only 2 plants, not yet ripe.
VI	Kaolin	0.135*	1 = 10 1 = 6	3½	Only 2 plants.
VII	Pipe Clay	0.120	2 = 5½ 1 = 5	1	
VIII	Sand alone	0.090	1 = 6 1 = 5 1 = 4	2	

* Only two plants.

contrasting the figures of the table on page 258 with those of the table next precedent, relating to green sand. It is highly improbable that either of the soils in the above list was richer in the inorganic constituents of plant food than green sand; and yet, thanks to the nitrogen natural to the peats and loams, they were able to bear, without any manuring, as good crops as were got from the green sand to which nitrates had been added.

The same point is still further illustrated by the experiments tabulated on page 259, which were made simultaneously with the experiments of page 258. The several jars contained similar mixtures of sand and loam, &c., in both series of experiments, but those of the table on page 259 were watered with a solution of phosphate of potash containing 0.25 gramme of that compound to the litre.

Analogous results were obtained from another set of jars that were watered both with a solution of phosphate of potash and of sulphate of lime. Thus, for example, there was obtained from jar No. 3 in that case 2.530 grammes of dry crop, and, from jar No. 8, 0.19 gramme.

The significance of the soil nitrogen will be seen from a somewhat different point of view in the following table of experiments (p. 261), made at the same time as the foregoing and under precisely similar conditions, in which the jars were watered with a liquid composed of equal volumes of a solution of nitrate of potash (1.25 grammes to the litre), and a solution of phosphate of potash (0.25 gramme to the litre).

Many other experiments of this sort have been made with the several peats and loams, both by themselves and admixed with various proportions of sand; and these mixtures have been watered with solutions of different salts and mixtures of salts, but the results have always pointed directly to one and the same conclusion; viz., that the soil-nitrogen was readily made use of by the plants, except in those cases where the physical condition of the soil was unsuitable for their life and growth.

It would be natural at this stage of the inquiry to illustrate the conclusion still further by calcining the several soils in order to destroy their organic matter, and then growing plants in the residual sand or ashes; but there is happily no need of taking any trouble of that sort since E. Wolff has done the very thing already in certain experiments made by him long ago, to prove the utility of nitrates and of ammonium salts considered as manures. As the result of many trials,

No. of the Jar.	The Jar contained a mixture of Sand (see page 258) and	The Crops			
		Weighed in grms. (Dried at 90° to 100°c.)	Grew to height in inches.	Had Seeds.	Remarks.
I	Plain-field Earth . . .	. 2.150 .	2 = 14 1 = 12	22	
II	Loam from Broadfields Farm.	1.775 .	1 = 15 1 = 13 1 = 10	5, and a few flowers.	
III	Loam from Mr. Saltonstall's Pasture . . .	2.790 .	. 3 = 17	33, and many flowers	None of the plants were ripe.
IV	Bussey Peat	. 3.040	1 = 17 1 = 15 1 = 13	32	
V	Dabney Peat.	. 1.590* .	1 = 15 1 = 13	5	Only 2 plants.
VI	Kaolin	. 1.630* .	1 = 16 1 = 14	14, and several flowers	Only 2 plants.
VII	Pipe Clay	. Lost .	1 = 15 1 = 14 1 = 9½	30	
VIII	Sand alone	. 0.620* .	1 = 13 1 = 10	6, and several flowers	Only 2 plants.

Wolff † found that oats and barley, and indeed "almost any kind of annual plant," may be grown just as well or even better in calcined loam or garden earth that has been mixed with a small proportion of an ammonium salt or a nitrate, as they can in the original uncalcined earth to which no fertilizer has been added.

Some sets of Wolff's experiments were made in pots of impermeable stoneware and others in glass jars. In some of the comparative trials he watered the soils with rain-water, and in others with distilled water; but one and the same conclusion was always reached. The plants grew normally and even luxuriantly both in the original garden earth and in the calcined earth to which nitrogeneous matters were added; but in those pots of the calcined earth which were left free from any addition of nitrogenized matters, the plants were always miserable dwarfs, of unhealthy aspect.

* Only two plants.

† See his "Praktische Düngerlehre," Berlin, 1872, pp. 5, 6, 15, 17; and his original papers, notably that in "Chemisch-Pharmaceutisches Central-Blatt,' 1852, **23**. 657.

It will naturally be asked, how it happened that Boussingault, in his experiments, already alluded to on page 252, arrived at conclusions so unlike those to be drawn from the results of Wolff and myself. I think the chief reason why the plants in Boussingault's trials derived so little support from the soil-nitrogen, will be found in the fact that the quantities of loam employed by him were both comparatively and absolutely very small. The following examples will give a general idea of the character of Boussingault's mixtures. They are taken from the first volume of his "Agronomie, &c.": —

The mixture consisted of	Page 299.	Page 304.	Page 331.	Page 348.	Page 352.
Garden Loam	130 grms.	130 grms.	130 grms.	100 grms.	50 grms.
Silicious Sand	1000 grms.	200 grms.	720 grms.	. . . .	125 grms.
Fragments of Quartz . .	500 grms.	300 grms.	150 grms.	75 grms.	. . . .
Ashes of Hay	0.2 grm.	0.1 grm.	0.1 grm.*	0.05 grm.*	0.05 grm.*
Phosphate of Lime . .	. . . .	. . . .	. . . .	0.1 grm.	0.1 grm.

Wolff, on the other hand, commonly took at least 200 grammes of earth, by itself, for each of his experiments, and apparently he sometimes used more. The quantities of peat and loam employed in my own experiments, as reported above, ranged from 230 to 500 grammes; and I have found by other experiments that less favorable results are obtained when quantities much smaller than these are employed, or when a very large proportion of sand or other inert material is mixed with the loam. The following table will illustrate the latter point. The experiments to which it refers were made in the spring

No. of Jar.	The Jar contained		Ratio of Loam to Sand.	The Crop, harvested May 22, 1873,		
	Loam from Bussey Plainfield, grms.	Berkshire Sand, grms.		Weighed in grms. Dried at 90° to 100° C.	Grew to height in inches.	Had Seeds.
1	. . 2000 . .	. . 0000 . .	1 : 0	. . 4.95 . .	11, 19, 25, 26	100
2	. . 1000 . .	. . 1000 . .	1 : 1	. . 2.91 . .	. 20 to 24 .	50
3	. . 800 . .	. . 1200 . .	1 : $1\frac{1}{2}$	. . 2.19 . .	8, 20, 21, 26	56
4	. . 500 . .	. . 1500 . .	1 : 3	Nothing grew		
5	. . 200 . .	. . 1800 . .	1 : 9	. . 0.25 †. .	. . 15 . .	5
6	. . 000 . .	. . 3000 . .	0 : 1	. . 0.18 . .	. . 7 . .	5

* Ash of dung.

† Only one plant. There were four plants in each of the other jars, excepting No. 4.

of 1873. Large glass jars were used to hold the mixtures, four buckwheat seeds were planted in each jar, and the mixtures were watered with rain-water.

The mixtures in jars Nos. 4 and 5 of this set of experiments were manifestly ill-suited for the growth of buckwheat. Not a single sprout appeared from the seeds that were planted in No. 4, and some germinated seeds that were subsequently planted in that jar failed to take root. The seeds originally planted in jar No. 5 likewise failed; but one of the four germinated seeds that were afterwards planted there grew with the results above stated. The small gain in the weight of crop No. 5 over and above the weight of that obtained in No. 6, from sand alone, has a certain interest in connection with some of Boussingault's results. For it is to be noted that his crops obtained from mixtures of loam and sand, equally unfavorable with those in Nos. 4 and 5 for the growth of plants, weighed more than the crops obtained by him under similar circumstances from mixtures that contained no nitrogen. Thus a maize plant grown by Boussingault (page 352) in a mixture containing: garden loam, 50 grammes; fragments of quartz, 125 grammes; ash of dung, 0.05 gramme, and phosphate of lime, 0.10 gramme, in which the ratio of loam to sand was as 1 to $2\frac{1}{2}$, gave a crop that weighed 0.675 gramme; while another maize plant grown (page 354) in a mixture of 125 grammes quartz fragments, 30 grammes powdered pumice stone, and 0.01 gramme ash of dung, gave a crop that weighed 0.289 gramme. In the latter case the dry crop weighed $1\frac{1}{3}$ times as much as the seed, and in the former a little less than three times as much as the seed.

So, too, a dwarf bean grown by Boussingault (page 348), in a mixture of 100 grammes loam, 75 grammes quartz fragments, 0.05 gramme ash of dung, and 0.1 gramme phosphate of lime (ratio of loam to sand = 1 to $\frac{3}{4}$), gave a crop that weighed 3.434 grammes, or $6\frac{7}{10}$ times the weight of the seed; another (page 315), grown in 50 grammes of loam by itself, gave a crop equal to 1.89 grammes, or $4\frac{1}{2}$ times the weight of the seed; another (page 312), grown in 40 grammes of the loam by itself, gave a crop equal to 1.1 gramme, or three times the weight of the seed; while one grown without loam (page 351), in a mixture of 100 grammes quartz fragments, 40 grammes pumice stone, and 0.1 gramme ash of dung, gave a crop equal to 0.967 gramme, or twice the weight of the seed.

Again, 2 hemp seeds planted in 40 grammes of the loam mixed with some fragments of quartz (page 309) gave a crop equal to 0.322 gramme, or five times the seed; while in a previous year (page 258), 6 hemp seeds planted in a mixture of 315 grammes quartz sand, 2 grammes phosphate of lime, and 0.3 gramme ash of hay, gave a crop equal to 0.305 gramme, or about twice the weight of the seeds.*

It is to be remarked that in many of Boussingault's experiments with sand or other inert matters mixed with the ash ingredients of plants, but totally devoid of nitrogen, he planted comparatively large seeds, such as those of lupins and beans, which contain in themselves so much nitrogen that the plants can grow to a considerable height at its expense. Attention has already been called in this "Bulletin," page 52, to the power of such plants to form new shoots and leaves by the repeated use of a single measure of nitrogen originally got from the seed. It is not at all strange, therefore, that dry crops, weighing three or four times as much as the original seed, should sometimes be obtained from soils devoid of nitrogen, when the seeds planted are large, and of kinds that are rich in nitrogen.

Doubtless one reason why so severe a conclusion against the significance of the soil-nitrogen has been drawn from Boussingault's experiments depends upon the indubitable fact that, in cold climates at least, there is a very clearly marked and a wide difference between the soil-nitrogen and the active forms of that element which are found in such compounds as the nitrates and ammonia-salts that are commonly used as manures. This difference is to be seen both in respect to the rapidity of action of the active forms of nitrogen upon the growth of plants, and the comparative slowness of action of the soil-nitrogen, and also in the greater or less degree of completeness with which the plants can consume the nitrogen of the diverse forms, or, in other words, remove it from a given volume of earth. Since one of the chief features of Boussingault's work consisted in the capital illustrations he gave of the great activity and usefulness of the nitrates as purveyors of nitrogen to the plant, it is no wonder that he himself was disposed to value but lightly the nitrogen of his garden soil when he found, for instance (page 321), that a pot containing 0.1 gramme of the element in that form gave a crop of hemp weighing only five

* Compare the early experiment of Boussingault ("Agronomie," **1.** 66), in which cresses grown in a sufficiency of garden soil yielded abundant crops.

times as much as the seed, while another pot that contained the same amount of nitrogen (0.1 gramme) in the form of a nitrate, gave a crop that weighed fourteen times as much as the seed, although, as has just been shown, the crop from the garden soil was two or three times as good as that from a soil totally devoid of nitrogen; or that he was surprised to find in his experiments with lupins that 0.34 gramme of the soil-nitrogen, that is to say, as much of that element as is contained in 2 or 3 grammes of saltpetre, gave crops that were but little if any better than those got from sands devoid of nitrogen, but charged with the ash ingredients of plant food.

The experiments made by Boussingault really proved, not that the soil-nitrogen is of little worth, but that, as is indicated by a mass of other evidence, it is generally speaking far less valuable than the nitrogen contained in manures. In other words, he found that very much more nitrogen, taken as it exists in loam, is required to produce a given effect, than when taken in the form of a nitrate or of an ammonium salt.

The following experiments by Professor Johnson,* of New Haven, afford an excellent example of the use that can be made of the soil-nitrogen by plants that are well supplied with the ash ingredients of

No. of the Pot.	The Pot contained	The Crop weighed, air dried, grms.		The Crop weighed more than the Seed, times
1 2	270 grms. of Peat	1.61 2.59	4.20	2½
3 4	270 grms. Peat, plus 10 grms. of ashes of young grass	14.19 18.25	32.44	20½
5 6	270 grms. Peat, plus 10 grms. of the ashes, and 10 grms. Carbonate of Lime	18.19 20.25	38.44	25½
7 8	270 grms. Peat, plus 10 grms. of the ashes, and 10 grms. of Hydrate of Lime	21.49 20.73	42.22	28½
9 10	270 grms Peat, plus 10 grms. of the ashes, and 5 grms. of Lime slaked with a strong solution of common Salt	23.08 23.34	46.42	30½
11 12	270 grms. Peat, plus 10 grms. of the ashes, and 3 grms. Peruvian Guano	26.79 26.99	53.78	35½

* Copied from his work entitled "Peat and its Uses," New York, 1866, p. 79.

their food, and are made moderately comfortable in respect to their physical surroundings. The experiments were made in earthen flower-pots. Five kernels of dwarf maize (pop-corn) were planted in each pot; and each of the trials was made in duplicate.

It is apparent that the experiments of Wolff really afforded a capital illustration of the importance of the soil-nitrogen for the support of plants. But, as has been said already, they were made to elucidate another matter; and, at the time when they were made, it was commonly believed that most soils contained considerable amounts of ammonium compounds available for the growth of plants. So long as that belief lasted, there was no special motive to consider the results from the present point of view; and Wolff's experiments consequently stood for no more than one item of proof, among many others, that plants can perfectly well make use of artificial supplies of ammonia. But so soon as it had been shown by the researches of Boussingault,* and of Knop and Wolf,† that there is usually no more than an insignificant trace of ammonia in the soil, the experiments of Wolff acquired a new meaning, for they point just as clearly to the presence in the soil of a supply of nitrogen useful for plants, as they do to the possibility of growing plants in the ashes of soil to which nitrates and ammonium salts have been added.

The results both of Wolff and myself agree perfectly with those obtained by Hellriegel ‡ and by Lawes, Gilbert, and Pugh,§ who, for the sake of controlling certain experiments made by them for other

* "Agronomie," **3.** 220.

† "Landwirthschaftliche Versuchs-Stationen," 1861, **3.** pp. 109, 207. In five different samples of soils, Knop and Wolf (p. 209) found no more than from 0.0001 to 0.00087 gramme of ammonia for every 100 grammes of the soil, regarded as absolutely dry.

In numerous samples of rain-water (p. 120) they found from 0.00003 to 0.0003 gramme ammonia to 100 grammes of the liquid; or, in other words, from 3 ten-millionths to 3 millionths. In the locality where the experiments were made, Mœckern, near Leipzig, there was usually no more than from one to two millionths of ammonia in the rain-water, though occasionally the proportion rose to three-millionths.

In dew and hail they found two-millionths of ammonia, and in snow from one to three-millionths. Well-water usually contains no ammonia, and the waters of rivers and ponds contain rather less than rain-water (p. 127).

‡ Hoffmann's "Jahresbericht," 1861, **4.** 112.

§ "Philosophical Transactions of the Royal Society of London," 1861, **151.** pp. 484, 535, 557, 574, and figure.

purposes, grew barley in the one case, and barley, wheat, and beans in the other, in pots of garden-earth that were watered with water that had been thoroughly freed from nitrogen compounds. These investigators obtained luxuriant crops from their pots of garden-earth, though the plants grown in this earth got no nitrogenous food beside that naturally contained in the soil. In the experiment of Lawes, Gilbert, and Pugh, the earth and plants were even shielded from the ammonia of the air, which was formerly supposed by some chemists to be sufficiently abundant to exert an appreciable influence upon the growth of plants.

It is remarkable that so little attention has been paid, of late years, not merely to these experiments, but to the great general fact, which has in reality long been known, that plants can in some way obtain a great deal of nitrogenous nourishment from the vast stores of nitrogen that are contained in the humus of the soil.* For from the moment when the fallacy of the notion that there is ammonia enough in the soil and air and rain to support the growth of wild plants of the higher orders had once been generally recognized and admitted, there has been urgent need not only of a true explanation of certain facts that had formerly been considered as part and parcel of the erroneous

* It was shown long ago by the analyses of Krocker ("Annalen der Chemie und Pharmacie," 1846, **58.** 381), and those published in 1849 by the Prussian Landes-œkonomiecollegium (cited in "Die landwirthschaftlichen Versuchs-Stationen," 1861, **3.** 214), that cultivated soils rarely contain less than 0.10% of their weight of nitrogen, and often much more. A. Müller (see Hoffmann's "Jahresbericht," 1862, **5.** 46, and 1866, **9.** 35), as the result of the examination of a considerable number of Swedish soils, found on the average 0.66% of nitrogen in the surface-soil of limestone regions, 0.26% of nitrogen in the surface-soil of regions poor in lime, and 0.15% in the subsoils of the latter. In several instances he found as much as from 0.90 to 0.96% of nitrogen. The proportion of nitrogen in the organic matters of these soils was on the average 4.6% in the case of the soils from limestone regions, and 3.7% in the soils poor in lime. The results of Müller are surprisingly similar to those obtained subsequently by Grouven (Hoffmann's "Jahresbericht," 1867, **10.** 35) in his analyses of a large number of German soils, fit for the growth of sugar beets. See, further, Hoffmann, in his "Jahresbericht," 1859, **2.** pp. 51–57. In the remarkably fertile "black earth" of Russia, Krocker found, in one instance, 0.4% of nitrogen, and E. Schmid (See Liebig & Kopp's "Jahresbericht," 1849, **2.** 660) from 0.33 to 0.99%. In 30 samples of American peats, Johnson ("Peat and its Uses," p. 83) found from 0.4 to 2.9% of nitrogen. In 11 analyses of European peats, collated by Websky (Hoffmann's "Jahresbericht," 1864, **7.** 7), the percentage of nitrogen ranges from 0.77 to 2.59.

doctrine, but also of a just appreciation of the significance of the so-called inert soil-nitrogen.* Much light has indeed been thrown upon the subject indirectly by experiments upon the formation of nitrates in the soil, as will be mentioned hereafter. But it would almost seem as if the not unnatural anxiety of chemists to detect and explain the conditions and circumstances under which the nitrogen of dead vegetable or animal matters may be changed into nitrates or ammonium salts had distracted the attention of many of them from the fundamental fact that under certain conditions the nitrogen of vegetable mould is, in part at least, available for the support of growing plants.

It is the purpose of the present paper to uphold this cardinal fact, and to urge that in the existing condition of agricultural knowledge it is equally important that the fact itself should be recognized and insisted upon, and the general conditions which influence or control it observed, as that the precise manner or form in which the nitrogen natural to the soil gets into the plant should be studied. It has been unfortunate that many chemists in their haste to discard certain erroneous views with which the subject was at one time encumbered, have well-nigh lost sight of several facts that were greatly insisted upon by some of the earlier chemists and by not a few agricultural writers. It would be unprofitable in the present connection to consider the various theories and speculations that led to this result, or even to dwell upon the old facts which the theories obscured; since there is no lack either of experimental proof with which to illustrate the present argument, or of examples that may be drawn from modern field practice. No matter how our knowledge of the truth that the soil-nitrogen may be used by plants has been acquired, it is manifest that the simple fact has a certain practical value which may be discussed as a subject by itself and upon its own merits, quite independently of any historical interest, or of the scientific question whether the nitrogen is first changed to a nitrate before the roots can absorb it, or whether it enters their pores in some form that is at present wholly unknown to us.

* Mulder (in his "Chemie der Ackerkrume," 2. pp. 153–183) has given an excellent summary of what was known about the nitrogen of the soil at the time when his book was written; but, as he wrote under the conviction that the soil contained much ammonia, the general tone of his discussion of the subject, and some of his conclusions, are very different from what they undoubtedly would have been if the real insignificance of the ammonia in the soil had been fully recognized.

It is undoubtedly true that in localities where artificial fertilizers can be readily procured, farming could be carried on successfully without the presence of any humus in the soil. This point has been proved not only on the small scale, by the experiments of Stœckhardt, Wolff, and many other observers, but by actual farming practice in Belgium.* But while it must be admitted, that, strictly speaking, the presence of humus in the soil cannot be accounted an indispensable condition for the growth of excellent crops, it is still true that most soils do contain more or less of it; that its nitrogeneous constituents are to a certain extent useful for the growth of plants; and that it is the farmer's business to cultivate his land in such manner that the best possible economic use shall be made of each and all of its ingredients.

Besides the familiar instances already cited of the growth of flowering-plants in pots filled with unmanured loam that is watered with rain-water, and of wild plants in the fields and forests that are supported by the stores of nitrogenous (and other) matters that have accumulated in the earth through the decay of precedent vegetation, several other striking illustrations of the fact will be found on studying the farming practices of various countries and localities where special manures of one kind or another are habitually used with success. Thus, it has long been known, from the writings of Bobierre and of Malaguti, that there are certain districts of France, and especially in Brittany, where the use of spent bone-black as a manure is attended with excellent results. Even fresh bone-black, and those kinds of waste bone-black that contain no nitrogen, produce useful effects in that region, especially when applied to land that has been newly broken up.† Since the use of spent bone-black by itself in this way, as a special manure, is peculiar to the agriculture of certain parts of France, and is a practice that has rarely, if ever, found favor elsewhere, it is but natural to inquire what circumstances are there peculiar to that region which can account for a custom so extraordinary? The explanation

* See Stœckhardt's "Chemische Ackersmann," 1856, **2.** pp. 41–54. Compare ibid., 1861, **7.** 193, and the well-known field experiments of Messrs. Lawes & Gilbert.

† See, for example, the recent edition of Bobierre's "Leçons de Chimie Agricole, Paris, 1872, the 11th Lecture, and elsewhere, as well as the earlier writings of that chemist, and the printed reports of Malaguti's Lectures at Rennes.

of the apparent anomaly is not far to seek. The country around Nantes and Rennes, and throughout the districts where bone-black is so largely used, is a region of granitic rocks rich in potash,* and the clayey or gravelly soils (*sols argilosiliceux*) that have resulted from the disintegration of these rocks, are naturally abundantly provided with one of the important elements of the food of plants; namely, potash. There is consequently little or no need of applying a "general" or "complete" manure to these soils. But it is plain, on the other hand, that the phosphatic element of plant-food is lacking in these soils, since long experience has shown that phosphate of lime applied to them in the form of bone-black serves an excellent purpose. The use of potash as a manure in that region seems to be well-nigh or even quite unnecessary; and it is clear, moreover, as it concerns us particularly to note in this connection, that the nitrogen naturally contained in the soil must play a very important part in supporting the crops that are obtained, since in actual farm practice the special phosphatic manure is used either with or without addition of nitrogeneous manure, accordingly as the soil of the field to which it is applied contains a small or a large proportion of vegetable remains. In other words, the bone-blacks that contain no nitrogen are used upon new land, as has been said, while those charged with blood and other albuminous matters are applied by preference to "soils that have been exhausted by a long course of cultivation" (Bobierre, *op. cit.*, p. 270.)

The use of wood-ashes by themselves here in New England and elsewhere, upon soils that are naturally poor in potash, is another instance of the same general character. It would be easy to cite a great number of experiments in which crops manured with ashes have manifestly made use of the nitrogen in the soil. The fact is particularly well illustrated in some of my own experiments upon the growth of barley, beans, and ruta-bagas upon a soil not specially rich in vegetable matters (see pages 89, 106, 136, and 140); since in these experiments not only wood-ashes but simple potash salts, such as the sulphate and the carbonate, applied in the pure state gave excellent results. It has been shown by Boussingault † that traces of cyanides and of other compounds of nitrogen are sometimes retained in the ashes of plants; but the

* Bobierre, *op. cit.* (page 106), gives the analysis of a gneiss from this region that contains nearly 8% of potash.

† In his "Agronomie," 1. pp. 86–93.

amount of nitrogen thus retained is usually exceedingly minute, and the experiments with carbonate of potash, and with sulphate of potash just alluded to, make it evident that the nitrogen which is so freely taken up by plants that have been manured with wood-ashes, cannot all have come from the paltry store within the ashes, but must have been derived for the most part from some other source. Even the ashes produced in the process known as paring and burning, doubtless act like ordinary wood-ashes upon the organic matters in the unburnt soil, and in that which has been half burnt or merely charred.

A specially noteworthy instance of the class now in question is found in the use of the so-called *cendres de marais*, or ashes of stable-manure, upon a rich tract of marsh land on the southwestern sea-board of France (Bobierre, *op. cit.*, pp. 122, 510). In default of other supplies of fuel, the inhabitants of that district burn the dung and litter of their farm animals, after it has been formed into cakes and thoroughly dried; and although little or no care is taken to protect the ashes from rain during the winter months, the fertility of the rich alluvial soil of the marshes is nevertheless kept up by means of heavy dressings of these ashes. The marsh lands in question are particularly rich in humus, and the fact that they yield an abundant supply of nitrogen to crops when manured, as has just been stated, with nothing but the ashes of dung, is really little more remarkable than the facility with which such soils naturally supply the nitrogen necessary for the support of wild plants when no manure of any kind has been applied to them. There can be no doubt, for instance, but that the fertility of the famous "black earth" of Southern Russia is largely dependent upon the nitrogenous matters that are contained in it, and the same remark is true of many soils in our own country. In several samples of prairie soils from Illinois, Dr. Vœlcker found noteworthy amounts of nitrogen;* and specimens of soil from the famous bottom lands of the Scioto River,† on which heavy crops of grain had been grown without interruption for a long term of years, were found to contain from 2 to 11% of organic matter. "The amount of nitrogenous compounds contained in this organic matter is undoubtedly

* See Caird, James, "Prairie Farming in America," New York, Appleton & Co., 1859, Appendix.

† Reported upon by D. A. Wells, "American Journal of Science," 1852, **14.** 11.

large, although not determined; the peculiar odor of these products while burning being very appreciable."

In all probability a good part if not the whole of the nitrogenous matters of these exceedingly fertile soils are very unlike those contained in ordinary peat or in moor-earth; but the variations in the quality of vegetable mould from different sources must generally be regarded rather as differences of degree than as actual distinctions in kind. Here in New England, many kinds of peat which are thought to do little or no good as manure, when applied directly to the land, produce distinctly useful effects after they have been mellowed by exposure to the weather. It is known that the quality of the nitrogenized constituents of vegetable mould depends largely upon the climate of the region in which the mould has formed. In high northern latitudes, and even in some less inclement regions, where the climate, though equable, and not excessively cold, is very moist, the decay of vegetable matters commonly produces moor-earth; while as the result of such decay in more temperate climates, like our own, we find peat of various degrees of consistency, including the matters that are commonly called "muck" in this vicinity. But in the tropics, peat is rarely if ever seen, except upon high mountains, though matters akin to leaf-mould are there abundant. In direct parallelism with these well-known geological facts, it would appear that the employment of active nitrogenous manures is more necessary for the successful cultivation of land in cold countries than in countries that are warm or hot.

On the one hand, the luxuriant growth of vegetation in a tropical swamp shows that woody plants can there obtain from the soil, with the utmost ease, all the nitrogen they need; while, upon the other, the good results that have been so constantly obtained by the use of nitrate of soda and of ammonia salts in the farming practice of England, Scotland, and Germany, illustrate the need there is in those climates of providing for certain crops an artificial supply of active nitrogen. But while it has been clearly proved for Northern Europe, that the natural supplies of nitrogen are altogether inadequate for the growth of maximum crops of grain, even upon soils that are highly charged with humus, very little is known as to the extent of country to which this dogma is applicable. There is still much to be learned with regard to the geographical and isothermal limits within which the use of artificial nitrogenous manures will be found to be necessary or

advantageous upon soils that are tolerably well charged with vegetable mould. "In hot countries," says Loudon,* "putrescent manures are not altogether neglected, but they are much less necessary than in cold countries, and can be done without where there is abundance of water; there, water, intense heat, and light, a consequently moist atmosphere, and a soil well pulverized by art, supply every thing necessary for luxuriant vegetation."

It is notorious that repeated crops of grain may be grown without manure in the rich alluvial soils of warm climates. In many parts of Hindostan and of the fertile East Indian islands manures are rarely if ever used. In certain localities of Spain, also, and the south of France, and of Sicily, as well as in some parts of Russia, grain has been grown continuously for very long periods. The bearing of this class of facts upon the present inquiry is somewhat less emphatic, however, than that of the examples previously cited, and of others that will be given hereafter; since in the East Indies, as in most hot climates, the crops may undoubtedly, in many instances, get a good deal of nitrogen from river-water applied to them by way of irrigation, or from the water with which the low-lying lands are naturally charged. In a hot country, where evaporation is rapid, the moisture in a soil must be drawn not only continually but quickly towards the surface, together, of course, with the matters which it holds dissolved. Nevertheless, it would seem to be plain that, in climates warmer than our own, the nitrogen of humus is more immediately available for the use of plants than it is hereabouts.

It is not unlikely that there is some truth in a belief that seems to be gaining ground in the Southern States of this country, to the effect that the nitrogen in such substances as fish-scrap, slaughter-house refuse, and the like, is there practically as useful pound for pound in a manure as the more active forms of nitrogen that are to be had in nitrate of soda or sulphate of ammonia. The true value of this opinion can hardly be determined except by repeated and long-continued intelligent observation and experimentation in actual field practice. For the present, the idea should be received with great caution, since the prevalence of it may be in some part due to the representations of persons interested in the sale of various commercial fertilizers that contain fish-scrap or flesh-meal. In view of the easy solubility and the lack

* In his "Encyclopædia of Agriculture," § 1251.

of fixity of the nitrates, there is little doubt but that in a country subject to heavy rains, nitrate of soda may often be found to be a less valuable fertilizer than an equivalent amount of fish-scrap, unless special care be taken to apply the nitrate by fractions at several different periods. In case the soil happens to stand in special need of phosphoric acid, as appears to be the case in some of the cotton-growing regions of the South, the difficulty of deciding as to the merits of the several kinds of nitrogenous fertilizers, is of course greatly increased, inasmuch as experiments made to that end are complicated and obscured by the action of the phosphoric acid naturally contained in fish-scrap and other manures of animal origin. In any event, the question must be a difficult one to decide, because of the great influence that moisture exerts (see beyond, page 279) upon the activity of the animal manures. They might invariably give good results on fields or in districts where the lay of the land is such that the surface-soil is adequately moistened by emanations from the ground water, and might constantly fail upon fields so situated as to be of necessity often dry.

The influence of climate upon the use of soil-nitrogen by plants has been well illustrated by the interesting researches of Stœckhardt and Peters * on the effect of high and low temperatures upon processes of disintegration and decay in the soil. These investigators filled two boxes, each with 50 German lbs. (25 kilogrammes) of a mixture of river sand and a sandy loam that contained but little humus, and two other boxes with a mixture of similar sand and loam to which 10% of vegetable mould taken from a hollow beech-tree had been added. One box in each of the pairs had a jacket or water-back filled with water which could be heated to any desired temperature by means of a system of pipes through which hot water was made to circulate. The boxes were of zinc, packed and sheathed without with non-conducting materials. All the boxes were placed on a scaffold outside a window, in a position tolerably well shielded from rain, and were exposed during three months to the summer weather of Tharand, near Dresden. But by means of the hot-water pipes, the temperature of the earth in the jacketed boxes was kept constantly 8° or 10° C. higher than that of

* Stœckhardt's "Chemische Ackersmann," 1864, **10.** 82, and "Die landwirthschaftlichen Versuchs-Stationen," **4.** 118. Compare "Chemische Ackersmann," 1863, **9.** 81, and 1871, **17.** 147.

the earth in the other two boxes. Maize and ray-grass were grown in all four boxes during the three months, at the end of which time the crops, though not yet mature, were harvested, and the weights of the dry products as well as their chemical composition, were compared. A few of the results of these experiments are given in the following table. The plants were watered with distilled water. Those grown in the earth rich in humus were in both boxes much better, larger, and greener than those grown in the sandy loam. Maize throve in the heated earth, and the grass supported the high temperature very well. But it was found by preliminary trials, that neither lupins, rape, nor oats prospered in the heated earth: —

There was harvested from the 50 lbs. of earth: —	Exposed to the temperature of ordinary summer air.		Exposed to the higher temperature.	
	In the Loam Box, grms.	In the Humus Box, grms.	In the Loam Box, grms.	In the Humus Box, grms.
Total Crop, dried at 110° C.	275	511	318	607
Carbon	110	214	130	260
Nitrogen	2.81	6.14	3.82	7.96
During the experiment the 50 lbs. of earth lost: —				
Organic matter	150	201	290	471
Carbon	70	100	156	279
Nitrogen	2.00*	5.25*	6.75	11.08
The 50 lbs. of earth contained before the experiment: —				
Organic matter	730	1231	730	1231
Carbon	380	664	380	664
Nitrogen	13.5	24.00	13.5	24.00

Other examples of the consumption of soil-nitrogen by crops are to be seen in the experience of many countries where lime is habitually applied to the land, and in the results of field experiments like those of Lawes & Gilbert,† for example, in which large quantities of nitrogen

* The risk of errors of observation due to the inherent difficulties of the investigation are to be kept in mind and allowed for, as well as the likelihood that some nitrogen may have been fixed in the soil in the manner alluded to on page 285.

† "Philosophical Transactions," 1861, **151.** 435.

have been taken off a given plot of land, year after year, in crops that were either not manured at all, or were manured with saline mixtures that contained no compound of nitrogen. The results of many experiments that have been made with gypsum and other sulphates, point in the same direction. It has been noticed again and again that the sulphates of lime, of magnesia, of soda, and of potash, tend to increase the growth not only of leafy plants, but of the leafy parts of plants, very much in the same way that the nitrogenous manures do, though less decidedly; and analysis has shown that plants manured with gypsum, or with Epsom salt, are often richer in nitrogenous constituents than those grown upon adjacent land that had not been manured. But it appears from the experiments of Dehérain,* that the sulphates neither promote the formation of nitrates nor of ammonium salts in the soil.

The old system of leaving land fallow, and in general the planting of the so-called fallow-crops before grain, undoubtedly depend in good part upon changes in the condition of the soil-nitrogen which those practices promote. The high estimation in which the better kinds of vegetable mould have always been held by practical men, as attested, for example, in a very forcible way by the stringent laws against the raking of leaves and the like from wood-land, that prevail in many parts of Europe, is another item of evidence not to be overlooked.

All considerations relating to the form or manner in which the soil-nitrogen is commonly consumed by plants have purposely been made subordinate, in this paper, to the exhibition of the empirical fact that, under certain conditions, such nitrogen can be used by plants in some way. There is no longer any doubt but that nitrogen may be taken up by plants in several, perhaps in many, different forms. Of late years, the idea continually gains ground, that the inert nitrogen of the soil is usually changed to the condition of a nitrate before it is taken up by plants; and there are a number of experiments, notably those of Boussingault, Cloez, and Bretschneider,† which prove that nitrates are easily formed through the oxidation of the soil-nitrogen, and that they are exceedingly important for the growth both of wild plants and

* See his "Cours de Chimie Agricole," Paris, 1873, p. 427.

† See Professor Johnson's "How Crops Feed," New York, 1870, pp. 254 to 288.

of cultivated crops. In almost any locality instances may be seen of forest-trees and other wild plants so situated that their nitrogenous food must manifestly be derived, in great part, if not wholly, from this source. In the immediate vicinity of Boston, for example, a great variety of weeds may be seen growing upon mere gravel in places where the original levels of the land have been changed to make room for the erection of buildings or for the laying out of roads, in such sort that the surface-soil has been completely dug away, and the subsoil laid bare; and their growth is doubtless to be explained by a reference to the nitrates and nitrogenized organic matters that are contained in the soil-water, and brought therewith to the roots of the plants by the capillary action of the gravel. It has been shown in a previous paper (pages 56–58), that the drift gravel of this vicinity can supply of itself the inorganic elements of plant-food, and several observers have found that well-waters often contain food enough of all kinds to support a tolerably vigorous growth.*

On the other hand, ammonia is doubtless produced from the soil-nitrogen in some cases,† though it can no longer be deemed to be abundant or even important in the sense that Liebig ‡ sometimes taught.

I am myself inclined to attach no little importance to the presence in the soil of minute forms of animal and vegetable life, that obtain their nitrogenous food directly from the vegetable mould, and yield in their turn, both by their excretions and by the decay of their dead bodies, a supply of nitrogenous compounds of the kinds that are fit to be taken up by plants. This idea is an old one. It was suggested by Ehrenberg, § who maintained long ago not only that microscopic animals

* Compare Johnson's "How Crops Grow," p. 171. For the amounts of nitrates that have been found in well and river waters, see Knop's "Agricultur-Chemie," **2.** 60.

† Compare Boussingault in his "Agronomie," **2.** pp. 18, 210; **3.** 196, and elsewhere; and Johnson in "Peat and its Uses," p. 45.

‡ See, for example, his "Theorie und Praxis in der Landwirthschaft," Braunschweig, 1856, p. 5.

§ According to Cohn, in Stœckhardt's "Chemische Ackersmann," 1863, **9.** pp. 221, 222. The idea has a certain resemblance to that of De Saussure ("Recherches," p. 166), who thought that the carbonate of ammonia which is evolved on subjecting vegetable mould to dry distillation must be derived in part from "insects that live in the humus and leave their remains there."

Compare the observations of Boussingault in his "Agronomie," **1.** pp. 344,

and plants abound in fertile soils, but that the fertility is to be ascribed in part to their presence. According to Cohn (*loc. cit.*, p. 219), diatoms abound not only in most natural waters, both fresh and putrid, but in every moist soil, whether it be that of swamps or the edges of ditches, of gardens, or of flower-pots. The dry loam of ordinary fields, though far less highly charged with microscopic forms of life, is by no means free from them.

The history of the derivation of the very name "infusoria" enforces the lesson that animalcules must be abundant wherever moist vegetable remains are in process of decomposition. According to Stein,* the term "*Infusionsthier*" was first used in 1763 by Ledermüller, because of the facility with which in winter weather he could procure living microscopic objects on allowing an infusion of hay in water to stand two or three days in a warm room. As Stein remarks, hay is specially well suited for the purpose in question, since it usually comes from meadows where the infusoria abound.

In this view of the matter, it is interesting to note the facts that it is in well-moistened soils such as the diatoms love to inhabit that plants are observed to avail themselves most readily of the soil-nitrogen, and that certain crops which can be grown without the help of nitrogenous manures, such as clover, beans, turnips, and other large-leaved plants, are precisely those which shade the soil and serve, like the process called mulching, to keep its surface moist. In the course of the experiments whose results have been recorded above on pages 254–261, I have repeatedly had occasion to notice the favorable influence that is exerted by an abundant supply of moisture upon the utilization of the soil-nitrogen by plants. The appearance of the plants thus thoroughly watered was comparable with that of plants growing in the moist soil of a closed glass case (Ward's case); and it may be noted in this connection that Boussingault † had no trouble in growing a good crop of cresses and of various weeds at the expense of the soil-nitrogen in an apparatus of that kind. The importance of moisture, as thus exhibited, recalls the results of practical field experience as to the use of oil-cake and certain other of the organic nitrogenous manures. Thus, even in a climate

345, and **2.** 340; that of Lawes, Gilbert, & Pugh, Philosophical Transactions, **151.** 532; and that cited by Mulder, "Chemie der Ackerkrume, **2.** 103.

* Stœckhardt's "Chemische Ackersmann," 1863, **9.** pp. 211, 212.

† "Agronomie," **1.** 67.

so moist as that of Scotland, it has been noticed * that rape-dust, which was formerly somewhat extensively employed there as a manure, often fails to be of use in very dry seasons and on dry soils. An adequate supply of moisture is essential to the production of its full effects. But since the nitrogen in rape-dust is notoriously more active and available for the use of plants than that in ordinary peat and loam, the fact that the usefulness of rape-dust depends so largely upon the contingency of a favorable season or a moist soil, teaches an important lesson. Not only does it suggest most emphatically that the less active soil-nitrogen needs to be kept similarly moist in order to its best action, but it points directly to the necessity of studying the soil-nitrogen for its own sake, of noting its peculiarities, and of determining clearly what conditions are most favorable to its usefulness. From the reports of the various agricultural societies of New England, it appears that mere peat or pond-mud often fails to produce useful effects when applied to land that seems to stand in need of vegetable matters, while in other instances distinctly beneficial effects are noticed. These differences are undoubtedly due in part to variations in chemical composition of the several peats or muds; but there can be little question that the failure of the peat or mud to act as a nitrogenous manure must often be attributed to the unfavorable conditions as regards moisture in which these substances were placed. They would be little likely to fail upon land needing nitrogen so situated that any organic matters that might be added to it would naturally be kept moist and mellow. But, as it happens, the land of fields thus advantageously placed is commonly so well charged with organic matters that peat alone is, comparatively speaking, seldom applied to it. Too much moisture is to be deprecated, of course. The soil must not be changed to a swamp, nor be kept so wet that it could become in the least degree boggy or sour. A properly moist and mellow soil may often be seen in fields and pastures on moving some stone, or clod, or piece of wood that has lain some time undisturbed, and observing the condition of the earth beneath. From the color and vigor of the grass, moreover, about the stone, it may be seen how useful the soil-nitrogen has there been found by the plants that had access to it. As an exhibition of the effects upon which the usefulness of mulching chiefly depends, this illustration leaves little to

* Anderson, in his "Elements of Agricultural Chemistry," Edinburgh, 1860, p. 196.

be desired. It shows, like the pot experiments previously described, how serviceable the soil-nitrogen may be under favorable conditions; and, like the experiments in question, it indicates very clearly one at least of the conditions that may justly be called favorable.

It is not improbable, moreover, that in some cases, and perhaps in many, certain organic nitrogenous constituents of the soil are consumed directly by the plant. Since it has been clearly made out that plants can take up and feed upon such compounds as urea, uric acid, glycocoll, and guanine, there is little reason to doubt that they could be equally well nourished by analogous compounds that might be formed in the earth. It appears indeed from the experiments of W. Wolf,* that plants grown by way of water culture in solutions containing tyrosin and leucine, substances that are known to be formed during the decay of the nitrogenous parts of fresh vegetable and animal matter, can obtain a supply of nitrogen from these substances, or from some product or products of their decomposition that contain neither ammonia nor nitric acid.

It is well known that a minute proportion of nitrogenized organic matter is to be found in most natural waters, and that traces of such matter may be dissolved on thoroughly leaching almost any kind of loam. Too little attention has sometimes been paid to the fact that crenic and apocrenic acids are nitrogenized bodies.† According to Mulder, these soluble acids occur in not inconsiderable quantities in every fertile soil.

The action of alkaline substances upon vegetable mould has an important bearing upon this side of the question. It is not at all improbable that the advantages gained by the use of alkalies as manures and in the compost heap may depend in good part directly upon the formation of compounds of the alkalies and nitrogenous matters that can be used as food by plants. There is no doubt but that, as a general rule, the use of the soil-nitrogen by crops is increased by applications of wood-ashes and of lime; and, as is well known, the inert nitrogen of peat and sods may be made, comparatively speaking, active and assimilable by composting these substances with an alkali, — either ashes, or lime, or soda-ash, or a mixture of lime and salt, or even with marl

* "Die landwirthschaftlichen Versuchs-Stationen," 1868, **10.** 13.

† See Mulder in his "Chemie der Ackerkrume," **1.** 349. Compare Detmer, "Die landwirthschaftlichen Versuchs-Stationen," 1871, **14.** 270.

and carbonate of lime in various forms. But the action of alkalies upon peat and loam is not merely to disintegrate or rot the organic matters; they tend furthermore to combine with them. Some of the compounds thus formed with the alkalies proper — viz., potash, soda, and their carbonates — are freely soluble in water;* and although these soluble compounds, on moving about in the soil, are undoubtedly soon changed to combinations that are far less soluble in mere water, that is no more than happens to all artificial fertilizers with the single exception of the nitrates; and there is on that account no reason to doubt but that the plant roots can find means to feed upon them. Lime, also, is known to combine directly with a great variety of nitrogenous matters to form useful manures, though, as a general rule, these compounds are difficultly soluble in water by itself.† According to Johnson,‡ it is quite possible to dissolve the whole of the humus in some kinds of brown peat by means of an alkali. This observer found, in several instances, that nothing but a residue of cellulose was left after the peat had been repeatedly treated with a dilute solution of carbonate of soda. But as Mulder (*loc. cit.*), and Detmer § have shown, the matter thus dissolved is distinctly nitrogenized.

It may here be remarked that practical farming experience, with

* See Mulder, G. J., "Die Chemie der Ackerkrume," Berlin, 1863, **1.** pp. 328, 333. Johnson, S. W., "Peat and its Uses," New York, 1866, pp. 85, 89.

A number of interesting experiments upon the use as manure of compounds such as are here in question were made long ago by Professor Lampadius, of Freiberg in Saxony. (See, for example, Erdmann's "Journal für tech. und ök. Chemie, 1832. **15.** pp. 291, 306, and the later volumes of that journal and its successor, the "Journal für praktische Chemie," notably the volume for 1835, **5.** 438). The practical advantages to be gained by composting peat and other forms of humus with ashes, lime, and other kinds of alkalies, are well known to farmers, and have been strongly insisted upon in this country by the late Dr. S. L. Dana, of Lowell (in his "Muck Manual for Farmers"), and by others. But the earlier observers were in no position to appreciate the significance of the nitrogen of the peat, or to form just conceptions as to the mode of action of the composts they prepared from it.

† Compare Knop, in his "Lehrbuch der Agricultur-Chemie," Leipzig, 1868, **1.** pp. 440, 444, 453; and Stœckhardt, in his "Chemische Ackersmann," 1860, **6.** 211.

‡ "How Crops Feed," p. 225, note. So, too, De Saussure ("Recherches Chimiques sur la Végétation," Paris, 1804, p. 167). "La potasse et la soude dissolvent presqu'en totalité le terreau végétal." Some kinds of humus, however, are far less soluble in alkali than others. See Mulder; also Detmer, "Die landwirthschaftlichen Versuchs-Stationen," 1871, **14.** 265.

§ "Die landwirthschaftlichen Versuchs-Stationen," 1871, **14.** 254, 258.

regard to the growth of clover and the other fallow crops before grain, tends to support the view that it is not in the form of nitrates alone that the soil-nitrogen becomes available as plant food. That wheat should grow freely after clover, on good land, much in the same way as if the land had received a dose of some nitrogenous fertilizer, can hardly be due solely to the accumulation of nitrates in the soil during the growth of the clover. For there is good reason to believe that the nitrates then formed would either be consumed by the clover itself, or be washed from the soil by rains. It is far more probable that a wheat crop grown after clover gets its nitrogenous food directly from the products of the decay of the roots and stubble of the clover. The growth of the fallow crop itself without the help of nitrogenous manure, under conditions in which a grain crop might starve, points to the conclusion that the soil-nitrogen must be used by the fallow crop also in other forms besides nitrates. If there were nitrates at hand, a grain crop would thrive, and there would consequently be small need of growing the fallow crop. It is precisely in the power of the fallow crop to supply itself with nitrogen in the absence of nitrates and ammonium salts that its chief merit consists.

The use of active nitrogenized manures in European field practice, upon rich soils, which, as has been already remarked, seems at first sight to cast a doubt upon the utility of the nitrogen already contained in those soils, is really not inconsistent with the view here presented. The practice in question may even be cited as an illustration of the importance of the soil-nitrogen, for it has often been noticed that the application of a very small quantity of active nitrogen in the form of nitrate of soda, or of an ammonium salt, produces an effect out of all proportion greater than the amount of nitrogen that was actually added to the land in the manure could of itself produce, while it is a matter of the commonest observation that the application to rich land of any considerable amount of such manure is actually dangerous, because of its liability to excite too rank a growth. An application of 112 lbs. of crude nitrate of soda, containing no more than 16 or 17 lbs. of nitrogen, to an acre of good land, has been known to double the grass crop. But a ton of hay contains some 25 lbs. or more of nitrogen, and a crop of 2½ tons would consequently carry off more than 60 lbs. of that element. It would seem, in this case, as if the driblet of active nitrogen added in the manure, must either help to start the crop and make it vigorous enough

to avail itself of the stores of less accessible nitrogen that are contained in the soil, or that a certain amount of one of the active forms of nitrogen is needed for the performance of some special physiological work within the plant, while the soil-nitrogen, or the products of its decomposition, may be perfectly competent to do the other kinds of work, or indeed most of the work that is required of that element in the process of building a plant.

The latter view would appear to derive some support from the familiar fact that some kinds of plants, such as the cereals, have far more need of the active forms of nitrogen than other plants of a different physiological habit, such as clover and turnips. It agrees, moreover, with certain differences in the behavior of plants towards solutions of nitrates, ammonium salts, and some other soluble forms of nitrogen, that have been repeatedly noticed in experiments made by way of water-culture or of sand-culture. The nitrates favor the growth of plants both young and old; but it has been found that plants reared by these methods have in general little liking for the nitrogen of ammonia compounds during the earlier stages of their growth. When very young, it appears to be difficult for the plants to assimilate the ammonia or even to bear its presence; but as they grow older this difficulty disappears or is very much lessened. The remark applies particularly to the phosphate of ammonia and nitrate of ammonia, by means of which plants have been successfully grown by the methods in question. The hurtful influence of sulphate of ammonia and chloride of ammonium, when used by themselves in sand or water culture, is a fact of another order, that is readily explained, since these salts are decomposed by the roots of plants in such wise that corrosive acids are produced which destroy the plants.* But this explanation fails to account for the behavior of the other ammonium salts, and especially that of nitrate of ammonia. I have myself noticed in experiments made with this salt curious anomalies analogous to those mentioned by Hellriegel.†

It would be of scientific interest, in this connection, to determine, by careful experiments, devised to that end, whether the minute traces of active nitrogen naturally contained in the rain-water with which the soils in my experiments were moistened, could possibly have had any

* See Johnson's "How Crops Grow," pp. 170–171.

† In Stœckhardt's "Chemische Ackersmann," 1873, 19. 223.

appreciable influence in helping the plants to obtain support from the soil-nitrogen. This point, it will be observed, is a distinct and separate question to be examined by itself. It has nothing to do with the fact that the traces of active nitrogen in rain-water are by themselves wholly inadequate for the growth of an ordinary crop. Nor indeed has it any immediate bearing upon the subject of the present paper. The experiments which have been recorded above show conclusively, on the one hand, that the soil-nitrogen is useful to plants under certain conditions, such as are found in nature; while, upon the other, they illustrate the fact, which Wolff had proved before, that soils devoid of vegetable mould, or of some other compound of nitrogen, will not support crops that can be put in comparison with those that are readily and constantly obtained from soils that contain peat or loam, or some other source of nitrogen.

The influence exerted by the impurities in rain-water upon the growth of plants in soils destitute of nitrogen is really so exceedingly small that it is hardly worthy of mention. I have satisfied myself by many trials that, regarded as a source of error, the influence of these impurities is so minute that it may safely be neglected excepting in the most refined experiments made for special purposes. There is an experiment of Hellriegel * which well illustrates this point. In an artificial soil that contained every thing, except nitrogen, necessary for the support of a maximum crop of barley, Hellriegel got a crop that weighed 0.184 gramme, when the pot was watered with the purest distilled water; while from a precisely similar pot, that was watered with rain-water, he got a crop that weighed 0.200 gramme. But from a third pot, similarly filled, and containing in addition an amount of nitrogen, in the form of a nitrate, equivalent to 84 lbs. of that element in 1,000,000 lbs. of soil, he obtained a crop that weighed 17.776 grammes. With regard to this matter, it should be noticed that the sands employed in my experiments naturally required and received more water to keep them moist, when they were used by themselves, than when peat or loam had been mixed with them.

I have not the least doubt but that, besides supplying nitrogen to plants, the humus of the soil may at times serve many other useful purposes, some of them dependent upon its chemical properties and others upon

* Stœckhardt's "Chemische Ackersmann," 1868, 14. 18.

its physical peculiarities; but the discussion of these points would be altogether foreign to the present inquiry. Their importance has indeed often been insisted upon. It is to be remarked, moreover, that the experiments and observations here presented do not in any way conflict with the exceedingly important conclusions that have been reached of late years, concerning the formation of active nitrogen compounds from the free nitrogen of the air * by the action of ozone, and in various processes of combustion and oxidation. The importance of such sources of nitrogen for the growth of plants in earlier geological epochs, and for the support of lichens, mosses, and other inferior forms of vegetation in our own times, can hardly be over-estimated. It is to be supposed, indeed, that the influence of these supplies of nitrogen, though exceedingly feeble, must be very widely felt. To them, undoubtedly, in the last analysis, the existing stock of soil-nitrogen is to be chiefly attributed. The fixation of the free nitrogen of the air by soils rich in organic matter, that has been noticed repeatedly by Boussingault,† and by other observers, and strongly insisted upon of late by Dehérain ‡ is another fact, perhaps of the same order, to be kept in mind. But there can be little doubt that, for the present support of agricultural crops, the vast stores of vegetable mould that have accumulated in the soil through the decay of many generations of plants, constitute a more abundant and a more important source of nitrogenized plant-food than any other.

* See Johnson's "How Crops Feed," New York, 1870, pp. 75–85.

† See, for example, his "Agronomie," **1.** pp. 303, 308, 321, 328 § 5, 336, and 344.

‡ In his "Cours de Chimie Agricole, Paris, 1873, p. 316, and in papers in the "Comptes Rendus" of the French Academy.

No. 12. — *Applied Zoölogy. The Importance of its Study to the Practical Agriculturist.* By D. D. Slade, M.D., Professor of Applied Zoölogy.

Zoölogy is that department of natural history which investigates and teaches the nature and properties of animals in general. Applied Zoölogy is this department restricted to those animals that man has especially subjected to his dominion, and which are commonly known as domesticated animals. In its broadest sense Applied Zoölogy includes all that pertains to these animals in health and disease. It is the study of their anatomy, physiology, pathology, and therapeutics. Anatomy teaches us the form, structure, and connection of every portion of the body, and its study in the widest sense exacts a previous knowledge of inorganic substances and the chemical laws which govern them. Physiology is the science which treats of the functions presented by organized bodies, animal or vegetable, — of the growth, chemical changes, and reproduction of these bodies. It requires an acquaintance with their mechanical, structural, and chemical composition, — in other words, with their anatomy. Anatomy is, then, the groundwork of physiology. A knowledge of these naturally leads to the study of the diseases of organic bodies; to pathology, as it is termed; and this in turn to therapeutics, or the cure of these diseases.

But why, it may be asked, is a knowledge of anatomy essentially important to the practical farmer? Because the laws governing the vital functions of animals — that is, animal physiology — cannot be properly understood without it. Nutrition, for example, comprehends not only all that relates to the substances which enter into the animal body, their different forms, quantities, and qualities, but also the processes of digestion and absorption, the circulation of the blood, the phenomena connected with respiration, and with the various excretions and secretions. In the feeding of stock, whether he has in view the growth and development of muscle, or the increase of fat, or the production of butter, the intelligent agriculturist should be acquainted with the physiological laws which govern these conditions, in order that he may attain the best results.

He should understand well the frame-work of the animal structure, the skeleton. He should comprehend that upon its form, proportions, and dimensions must depend the beauty and strength of the animal, and its fitness for the end proposed. He should know that this frame-work itself should be perfect, in order that all the physiological functions should be properly performed. Thus, no animal could be considered in a normal condition with a malformation of the bony chest, interfering as it necessarily would with the healthy performance of the functions of the lungs. His anatomical knowledge should teach him whether the form of the chest, the length of the spinal column, the size and shape of the head, the length and position of the extremities, the age of the animal as indicated by the teeth, will or will not suit his purpose; whether the motive powers of the bony structure, the muscles, are so disposed as to contribute as much as possible to the strength and speed of the animal.

Again, without a knowledge of anatomy, the farmer is really unfitted to treat many of the diseases and accidents to which the domestic animals are so liable. Take, for instance, the horse's foot, disclosing such beauty of design, — how can any man, without a familiarity with its structure, successfully cope with its various diseases, or even direct the mechanical operations of the farrier! On the other hand, by the aid of this knowledge, he is able to understand and to explain to others natural processes and the reasons of many natural phenomena. Thus he will know that, while in all the domestic animals the process of digestion is for the most part the same, the anatomy of the digestive organs of his cattle and sheep is different from his own, and is adapted to the great amount of food necessary for the proper nutrition of these animals. He will comprehend why the respiration of a horse cannot be aided by any dilatation of the mouth, and why this animal cannot vomit; why it is best to give liquid substances to ruminating animals slowly, and why the tongue should be left free during their administration.

His knowledge of physiology will enable him to look upon his stock otherwise than as so many living machines for the conversion of certain articles into muscle, fat, or butter. It will also enable him to understand why the administration of drugs should be guided by reason and common sense, instead of by blind adherence to long continued custom; that the action of drugs varies not only in the differ-

ent species of animals, but even in animals of the same class, being innocuous in some, and in others poisonous.

It may be asked to what extent are these scientific pursuits to be followed by the practical farmer, or by those who intend to become such? Are they absolutely essential to success in agricultural pursuits?

In answer, we reply that much must depend upon circumstances, and upon the means and opportunities at the disposal of farmers. It is not to be expected that they will become experts in the veterinary art; but they should have acquired that amount of knowledge which will enable them to treat in a rational way the most common diseases of their animals, to be of service to themselves and their neighbors in time of need, to know when to call in more skilful aid, and in a measure to be instrumental in dispelling the vast amount of ignorance, barbarism, and superstition that so extensively prevail in our country. This knowledge, however, is not to be acquired by the simple reading of books. It implies a diligent and faithful attendance upon recitations and lectures, the study of anatomy by dissection, and the examination of the various pathological specimens which may be presented.

We do not deny but that long-continued and well-directed observation, combined with careful judgment, may be of vast assistance to the agriculturist, but he cannot expect that certainty in results which follows experiments based upon scientific acquirements. We do not imagine that Robert Bakewell,* for example, the noted improver of

* Robert Bakewell, born at Dishley, in Leicestershire, in 1725, occupied the same estate that his father and grandfather had resided on before him. Youatt, in his work on Cattle, says: "Having remarked that domestic animals in general produced others possessing qualities nearly similar to their own, he conceived that he had only to select from the most valuable breeds such as promised to return the greatest possible emolument to the breeder, and that he should then be able, by careful attention to progressive improvement, to produce a breed whence he could derive a maximum of advantage. Under the influence of this excellent notion, he made excursions into different parts of England, in order to inspect the different breeds and to select those that were best adapted to his purpose and the most valuable of their kind; and his residence and his early habits disposed him to give the preference to the long-horn cattle. In Bakewell's opinion, every thing depended on breed; and the beauty and utility of form, the quality of the flesh, and the propensity to fatness, were, in the offspring, the natural consequence of similar qualities in the parents. By judicious breeding, in uniting the superior branches of the same breed, he produced a stock unrivalled in his day." A writer † describes him as "a tall,

† "Wet Days at Edgewood," by Donald G. Mitchell.

stock, was an anatomist in the common acceptation of the term, for his education was very limited; and yet by close observation and by long-continued experience he laid down certain fundamental principles by which he was guided, and by which he brought about excellent results. There are some men, like Bakewell, who may understand the animal structure best adapted for the purposes they have in view without pursuing the study of anatomy or physiology. Such men are, however, very rare; and what they acquire by a sort of instinct, the great majority are obliged to attain by careful study.

It is not the present purpose of this Professorship in the Bussey School to make veterinary practitioners of those who may seek its instruction, but to offer them just such advantages as we have described. And these advantages are particularly applicable to young men who are or who intend to become practical farmers, to those who will be called upon to manage large estates either as owners or as overseers, and to those persons who wish to familiarize themselves with the structure of those animals in which they take pride and interest. To become veterinary practitioners in the true sense of the term, demands long, diligent, and careful study, — in short, a thorough education, — and it is vain to suppose that this can be accomplished without such training. Nay, it would seem, under many circumstances, to require a more thorough preparation than even the practice of human medicine; for in the former, from the incapacity of the sufferer to describe his own sensations, the physician is deprived of a most important source of information both in the detection of symptoms and in the effects of remedies. "Miserable animal," says St. Bel, "bereft of speech, thou canst not complain, when to the disease with which thou art afflicted excruciating torments are superadded by the ignorant efforts of such men, who at first sight, and without any investigation to lead them to the source of thy disorder,

stout, broad-shouldered man, of a swarthy complexion, clad usually in a brown loose coat, with scarlet waistcoat, leather breeches, and top-boots. In this dress and in the kitchen, where hung the separate joints and points of the more celebrated of his cattle, preserved in pickle, as well as the skeletons of the different breeds, he entertained Russian princes, French and German royal dukes, British peers and farmers, and sight-seers of every degree. All his guests, whether high or low, were obliged to conform to the farmer's rules. Breakfast at eight o'clock, dinner at one, supper at nine, bed at eleven o'clock; at half-past ten, let who would be there, he knocked out his last pipe."

pronounce a hackneyed common-place opinion on thy case, and then proceed with all expedition to open thy veins, lacerate thy flesh, cauterize thy sinews, and drench thy stomach with drugs adverse in general to the cure they engage to perform."

And in this connection we cannot refrain from adding a few remarks in behalf of veterinary science. It is difficult to explain why there should exist such complete apathy upon this subject throughout our country, especially when we take into consideration the vast interests at stake. Scientific and agricultural schools have been established, and have been largely endowed, and not until comparatively lately has any provision been made for instruction in this science. Not a single national or state veterinary college exists. All that can be said in justification of this long neglect (if justification it can be called) is that we have followed the course of older nations. In Great Britain, for example, it is only at a comparatively recent period that veterinary medicine has been recognized among the liberal arts, and the practice regarded as by no means incompatible with the dignity of a man of education. In France, Germany, and in Italy, the science has been long cultivated, and its teachers have been held in high estimation. In fact their labors and researches have contributed largely to the advance of modern physiology.

That the profession has been highly appreciated by the great of both ancient and modern times, we have ample testimony. Both Homer and Xenophon wrote upon the horse, — the latter a treatise on equitation. "When Xenophon wrote his rural treatises, he was living in that delightful region of country which lies westward of the mountains of Arcadia, looking toward the Ionian Sea. Here, too, he wrote the story of his retreat and his wanderings among the mountains of Armenia; here he talked with his friends, and made other such *symposia* as he has given us a taste of, at the house of Callias, the Athenian; here he ranged over the whole country-side with his horses and dogs; a stalwart and lithe old gentleman, without a doubt; able to mount a horse or to manage one with the supplest of the grooms; and with a keen eye, as his book shows, for the good points in horse flesh. A man might make a worse mistake than to buy a horse after Xenophon's instructions, to-day. A spavin or a windgall did not escape the old gentleman's eye, and he never bought a nag without proving his wind and handling him well about the mouth and

ears. His grooms were taught their duties with nice speciality; the mane and tail to be thoroughly washed; the food and bed to be properly and regularly prepared, and treatment to be always gentle and kind. Exception may perhaps be taken to his doctrine in regard to stall floors. Moist ones he says injure the hoof. Better to have stones inserted in the ground close to one another, equal in size to their hoofs; for such stalls consolidate the hoofs of those standing on them, besides strengthening the hollow of the foot."*

The great Hippocrates did not hesitate to combine veterinary with human medicine, exercising his skill upon the horse as well as upon his rider. He even wrote a treatise upon the curative treatment of horses.

Among the Latins, we may mention Vegetius, styled the Veterinary Hippocrates, who flourished three hundred years after Christ, and in whose writings were concentrated all that had been collected by former veterinary authors.

Coming down to modern times, among the patrons of this science, we find, in the sixteenth century, Francis the First, who by causing the translation of Greek authors into Latin, and afterwards into the modern languages, disseminated knowledge throughout Europe. Among the great works thus spread abroad were those of Vegetius. Near the end of the seventeenth century a large volume was issued by Sollysel, who was a riding-master; and, as his school was in great repute at this time, it followed that the treatment of equine diseases became very much confined to the masters of the art of equitation, which was an injury to the progress of veterinary science, inasmuch as it fell in a great measure into the hands of persons who had not received a medical education. Without enumerating the many distinguished writers on this science who appeared during the eighteenth century, we may mention that, in 1761, France, under the royal patronage, established a public veterinary college at Lyons, having the celebrated Bourgelat as professor; and, in 1766, a second public school was opened at Alfort; and others subsequently at Strasbourg and Montpellier. Contemporary with Bourgelat, and instructor at Lyons, was La Fosse, who, by his writings and discoveries, communicated in the form of memoirs to the Royal Academy of Sciences at Paris, did very much towards the advancement of veterinary medi-

* Op. cit. p. 19.

cine. In Great Britain, strange as it may seem, very few original writings appeared, and very little progress was made in the science, until the present century. The London Veterinary College was established in 1791–92, and had, for its originator and first professor, St. Bel, who had been educated at Lyons. Within the present century the English school has put forth many standard works, and among its zealous promoters have been John Hunter and Sir Astley Cooper.

In our own country, with very few exceptions, we have thus far been dependent upon those who have received their education in foreign lands for all the science and skill we could command. We know of no field which offers such an abundant harvest both for fame and pecuniary remuneration to young men of thorough education and enterprise; and it is difficult to understand why some of those who crowd the ranks of the medical profession should not take advantage of this golden opportunity.*

* In a letter recently received from Professor James Law, of Cornell University, he says: "Few of my students in this university have studied with the view of becoming veterinary practitioners, and, of these few, most, having acquired a liking for the subject here, have then gone to some regular veterinary school, because they could there graduate two years sooner. The public estimation of the subject is so low that it is not easy to convince people of the need for a thorough study of its principles. Half-educated men going out with degrees tend to perpetuate this low status. We have only granted two veterinary degrees in the six years of our existence as a university."

No. 13. — *Report of the Director of the Arnold Arboretum, presented to the President and Fellows of Harvard University.*

To the President of the University: —

Sir, — I have the honor to submit the following report of the present condition of the Arnold Arboretum, and of its progress during the two years which have passed since I was intrusted with the direction of its formation.

The very limited means at the disposal of the Director have, of necessity, made these two years, years of preparation and organization.

A Catalogue of the ligneous plants growing spontaneously, or by introduction, previous to 1872, on that portion of the "Bussey Farm" which is to be devoted to the Arboretum, has been made. (See *Appendix* A.)

The soil and indigenous growth on the various portions of the grounds have been carefully studied with a view to a proper determination of the permanent location of the various collections, and several thousand trees and shrubs have been raised for the future plantations. (See *Appendix* B.)

An inspection of the trees already growing in the Arboretum showed that many of them were in a miserable condition from long neglect of proper thinning, and the consequent want of food, light, and air. To remedy this as far as possible, the woods and old plantations have been gradually thinned out, the weak, deformed, and unhealthy plants being cut first, and then such as interfered with fine single specimens, or with specimens of only occasional occurrence. Returning health in many of the trees, and the greatly improved appearance of the woods and belts of timber is already apparent, although the operation of thinning out old woodlands, with a view to forming healthy, well-developed trees, is necessarily a slow one, and must be extended over many years.

Already many noble specimens of some of the finest native trees are scattered through the open portions of the grounds, promising dignity and interest to the Arboretum, and proving that the situation is particularly adapted to the use to which it is to be devoted.

I am under deep obligation to Dr. Asa Gray for the valuable assistance and advice with which he has honored me from the very outset

of the undertaking, and for an introduction to his numerous correspondents both in America and Europe.

I take this occasion to acknowledge the following contributions: —

Many seeds of European and Asiatic trees and shrubs from the Royal Gardens, Kew, through its Director, Dr. J. D. Hooker. Several collections of seeds, especially of the trees of Eastern Asia, from the Jardin des Plantes, through its Director, Prof. Decaisne. Collections of seeds of the trees and shrubs of Siberia and the North of China from the Imperial Botanic Garden at St. Petersburg, through its Director, Dr. Ed. Regel.

Large and full collections of seeds of the trees and shrubs of Ohio and the neighboring States, from W. C. Hampton, Esq., of Mt. Victory, Ohio.

Large collections of seeds of the trees and shrubs of Virginia, from A. H. Curtiss, Esq., of Liberty, Va.

My thanks are due to Dr. Kellogg, of San Francisco, and to Dr. H. N. Bolander, late State Botanist of California, for extensive and valuable collections of Californian seeds; and to J. G. Lemmon, Esq., of Sierra Valley, California, to whose energy and zeal I am indebted for a large quantity of seed of some of the rarer Californian Coniferæ, and for many other valuable contributions.

My thanks are also due to Dr. C. C. Parry, of Davenport, Iowa, for seeds of the Rocky Mountain Coniferæ, and to Dr. George Engelmann, of St. Louis, for seeds of the rare *Abies concolor*, and of several species of Oak.

To T. S. Brandigee, Esq., of Cañon City, Colorado, and to A. L. Siler, Esq., of Osmer, Kane Co., Utah, I am indebted for seeds of the trees of their respective localities, some of which are entirely new to cultivation.

I am also indebted to Messrs. Pinney & Co., of Sturgeon Bay, Wisconsin, for coniferous seed; to Dr. J. H. Mellichamp, of Bluffton, South Carolina, for seeds of some of the rarer ligneous plants of that State; to H. H. Hunnewell, Esq., of Wellesley, Mass., for seed of the rare *Larix leptolepis*; to W. R. Mercer, Esq., of Doylestown, Penn., and to Mrs. Mary Treat, of Vineland, New Jersey, for seeds collected in their respective localities.

C. S. SARGENT, *Director.*

December 1, 1874.

APPENDIX A.

A Catalogue of the Ligneous Plants growing in the Arnold Arboretum. September 1, 1874.

The Asterisk (*) denotes that the Plant is not growing spontaneously.

Clematis Virginiana, L.
*Magnolia umbrella, Lam.
*Liriodendron Tulipifera, L.
Berberis vulgaris, L.
Tilia Americana, L.
*Tilia Europæa, L.
Rhus glabra, L.
Rhus copallina, L.
Rhus venenata, DC.
Rhus Toxicodendron, L.
Rhamnus catharticus, L.
Ceanothus Americanus, L.
Celastrus scandens, L.
*Æsculus Hippocastanum, L.
*Acer Pseudo-platanus, L.
Acer saccharinum, Wang.
Acer rubrum, L.
*Caragana frutescens, DC.
Robinia Pseudacacia, L.
*Colutea arborescens, L.
*Gleditschia triacanthos, L.
*Prunus avium, Moench.
*Prunus Chamæcerasus, Lois.
Prunus Virginiana, L.
Prunus serotina, Ehrh
Spiræa salicifolia, L.
Spiræa tomentosa, L.
Rubus strigosus, Mich.
Rubus occidentalis, L.
Rubus Canadensis, L.
Rubus hispidus, L.
Rosa lucida, Ehrh.
Rosa Carolina, L.
*Rosa cinnamomea, L.
*Rosa Alpina, L.
*Cratægus Oxyacantha, L.
Cratægus tomentosa, L.
Amelanchier Canadensis, Torr. & Gray.
var. Botryapium, Gray.
*Pyrus communis, L.
*Pyrus malus, L.
*Pyrus aucuparia, Gærtn.
Pyrus Americana, DC.
*Philadelphus coronarius, L.
Hamamelis Virginica, L.
Cornus alternifolia, L.
Cornus stolonifera, Mich.
Cornus paniculata, L'Her.
Cornus florida, L.
Sambucus Canadensis, L.
Viburnum Lentago, L.
Viburnum dentatum, L.
Viburnum acerifolium, L.
*Viburnum Opulus, L.
*Symphoricarpus racemosus, Mich.
*Lonicera Etrusca, Santi.
*Lonicera Tartarica, L.
Lonicera ciliata, Muhl.
Cephalanthus occidentalis, L.
Gaylussacia frondosa, Torr. & Gray.
Gaylussacia resinosa, Torr. & Gray.
Vaccinium Pennsylvanicum, Lam.
Vaccinium corymbosum, L.
Vaccinium macrocarpon, Ait.
Gaultheria procumbens, L.
Andromeda ligustrina, Muhl.
Azalea viscosa, L.
*Rhododendron Catawbiense, L.
Ilex verticillata, Gray.
*Catalpa bignonioides, Walt.
*Lycium vulgare, Dunal.
*Syringa vulgaris, L.
*Ligustrum vulgare, L.
*Fraxinus excelsior, L.
Fraxinus Americana, L.
Lindera Benzoin, Meisner.
Ulmus Americana, L.
*Ulmus campestris, L.

*Ulmus montana, Wither.
*Morus rubra, L.
*Morus alba, L.
Platanus occidentalis, L.
Juglans cinerea, L.
Carya alba, Nutt.
Carya tomentosa, Nutt.
Carya porcina, Nutt.
Carya amara, Nutt.
Quercus alba, L.
Quercus bicolor, Willd.
Quercus ilicifolia, Wang.
Quercus coccinea, *var.* tinctoria, Gray.
Quercus rubra, L.
Castanea vesca, L.
Fagus ferruginea Ait.
Corylus Americana, Walt.
Ostrya Virginica, Willd.
Carpinus Americana, Mich.
Myrica cerifera, L.
Comptonia asplenifolia, Ait.
Betula lenta, L.
Betula alba, *var.* populifolia, Spach.
Alnus incana, Willd.
*Salix ——— ?
Salix ——— ?
Salix ——— ?
*Populus alba, L.
Populus tremuloides, Mich.
Populus grandidentata, Mich.
*Pinus sylvestris, L.
*Pinus Laricio, Poir.
Pinus rigida, Miller.
Pinus Strobus, L.
*Abies nigra, Poir.
*Abies excelsa, DC.
Abies balsamea, Mars.
Abies Canadensis, Mich.
*Larix Europæa, DC.
*Chamæcyparis obtusa, Sieb. & Zucc.
*Thuja occidentalis, L.
Juniperus Virginiana, L.
Juniperus Sabina, *var.* procumbens, Pursh.
*Juniperus Chinensis, L.
Smilax rotundifolia, L.
Smilax herbacea, L.

APPENDIX B.

A CATALOGUE OF THE LIGNEOUS PLANTS RAISED AT THE ARNOLD ARBORETUM DURING THE TWO YEARS ENDING DECEMBER 1, 1874.

Clematis Douglasii, Hook.
Clematis Virginiana, L.
Magnolia glauca, L.
Magnolia umbrella, Lam.
Asimina triloba, Dunal.
Cocculus Carolinus, DC.
Menispermum Canadense, L.
Akebia quinata, Decne.
Berberis vulgaris, L.
var. asperma, Hort.
var. asperula, Hort.
var. dulcis, Hort.
var. emarginata, Hort.
var. purpurea, Hort.
var. Sibirica, Hort.
Berberis Canadensis, Pursh.
Berberis Sinensis, Desf.
Isomeris arborea, Nutt.
Cistus Corbariensis, Pourr.
Cistus laurifolius, L.
Helianthemum serpyllifolium, Mill.
Helianthemum roseum, DC.
Hypericum Androsæmum, L.
Hypericum prolificum, L.
Tilia platyphylla, Scop.
Zanthoxylum Americanum, Mill.
Ptelea trifoliata, L.
Ailanthus glandulosus, Desf.
Rhus copallina, L.

Vitis cordifolia, *var*. riparia, Gray.
Vitis heterophylla, Thumb.
Rhamnus catharticus, L.
Rhamnus infectorius, L.
Rhamnus Frangula, L.
Ceanothus Americanus, L.
Celastrus scandens, L.
Euonymus atropurpureus, Jacq.
Staphylea trifolia, L.
Staphylea Bumalda, DC.
Kœlreuteria paniculata, Laxm.
Æsculus glabra, Willd.
Æsculus flava, Ait.
var. purpurascens, Gray.
Acer spicatum, Lam.
Acer circinatum, Pursh.
Acer glabrum, Torr.
Acer rubrum, L.
Acer ——— ?
Negundo aceroides, Moench.
Laburnum vulgare, Griseb.
var. involuta, Hort.
var. grandiflora, Hort.
var. fragrans, Hort.
var. autumnalis, Hort.
var. Waterer's, Hybrid, Hort.
var. quercifolia, Hort.
var. Adami, Hort.
var. arvensis, Hort.
var. pendula, Hort.
Laburnum alpinum, Griseb.
Genista radiata, Scop.
Genista virgata, DC.
Genista aphylla, DC.
Genista Ætnensis, DC.
Genista tinctoria, L.
Spartium junceum, L.
Ulex Europæus, L.
Cytisus albus, Link.
Cytisus albus, *var*. monstrosa, Hort.
Cytisus nigricans, L.
Cytisus scoparius, Link.
Cytisus capitatus, Jack.
Caragana microphylla, DC.
Caragana frutescens, DC.
Caragana frutescens, *var*.
Colutea arborescens, L.
Colutea cruenta, Ait.
Colutea Haleppica, Lam.
Cladrastis tinctoria, Raf.
Sophora speciosa, Shule.
Cercis occidentalis, Torr.
Gymnocladus Canadensis, Lam.
Gleditschia triacanthos, L.
Gleditschia Sinensis, Lam.
Gleditschia ferox, Desf.
Acacia Rœmeriana, Schlecht.
Prunus Americana, Marshall.
Nuttallia cerasiformis, Torr. and Gray.
Spiræa opulifolia, L.
Spiræa chamædrifolia, *var*. oblongifolia, Camb.
Spiræa trilobata, L.
Spiræa salicifolia, *var*. carnea, Ait.
Spiræa salicifolia, *var*. semperflorens, Hort.
Spiræa ariæfolia, Smith.
Spiræa callosa, Thumb.
Spiræa callosa, *var*. glabra.
Spiræa sorbifolia, L.
Spiræa aruncus, L.
Spiræa vaccinifolia, Don.
Spiræa cratægifolia, Link.
Spiræa Nobleana, Hook.
Exocorda grandiflora, Lindl.
Cercocarpus parvifolius, Nutt.
Rubus suberectus, Anders.
Rubus strigosus, Mich.
Rubus laciniatus, Willd.
Rubus cordifolius, Weith & Ness.
Rubus tiliæfolius, Weith & Ness.
Rubus leucostachys, Schleich.
Rubus rhamnifolius, Weith & Ness.
Rubus villosus, Ait.
var. flora-pleno, Hort.
Rubus deliciosus, Torr.
Rubus rudis, Weihe.
Rubus thyrsoideus, Wimm.

Rubus parvifolius, L.
Rubus mucronatus, Ser.
Rosa macrophylla, Lindl.
Cratægus Pyracantha, Pers.
Cratægus pyrifolia, Ait.
Cratægus coccinea, L.
Cratægus tomentosa, *var.* mollis, Gray.
Cratægus marroccana, Pers.
Cratægus tanacetifolia, Pers.
Cratægus Oxyacantha, L.
var. fusca, Hort.
var. flava, Hort.
var. orientalis, Hort.
var. incisa, Hort.
var. stricta, Hort.
var. laciniata, Hort.
var. Oliveriana, Hort.
var. ilicifolia, Hort.
Cratægus melanocarpa, Bieb.
Cratægus sanguinea, Pall.
Amelanchier vulgaris, Mœnch.
Pyrus parviflora, Desf.
Pyrus floribunda, Lindl.
Pyrus spectabilis, Ait.
Pyrus prunifolia, Willd.
Pyrus coronaria, L.
Jamesia Americana, Torr. & Gray.
Philadelphus coronarius, L.
Philadelphus grandiflorus, Willd.
Philadelphus Gordonianus, Lindl.
Hydrangea arborescens, L.
Liquidambar styraciflua, L.
Cornus stolonifera, Mich.
Cornus paniculata, L'Her.
Cornus florida, L.
Cornus Nuttallii, Audubon.
Nyssa multiflora, Wang.
Sambucus nigra, *var.* virescens, Hort.
Sambucus racemosa, L.
Sambucus pubens, Mich.
Viburnum opulus, L.
Lonicera Etrusca, Santi.
Lonicera flava, Sims.
Lonicera Tartarica, L.
Lonicera Xylosteum, L.
Lonicera involucrata, Banks.
Lonicera cærulea, L.
Lonicera Iberica, Bieb.
Lycesteria formosa, Wall.
Cephalanthus occidentalis, L.
Erica vagans, L.
var. purpurascens, Bree.
Andromeda ligustrina, Muhl.
Oxydendrum arboreum, DC.
Dabœcia polifolia, G. Don.
Rhododendron Catawbiense, Mich.
Rhododendron chrysanthum, Pall.
Ilex verticillata, Gray.
Callicarpa Americana, L.
Fraxinus Ornus, L.
Fraxinus excelsior, L.
Fraxinus Americana, L.
Aristolochia Sipho, L'Her.
Persea Carolinensis, Nees.
Elæagnus argentea, Pursh.
Ulmus montana, Wither.
Ulmus racemosa, Thomas.
Planera crenata, Desf.
Celtis Australis, L.
Celtis Tournefortii, Lamb.
Celtis Sinensis, Persoon.
Celtis occidentalis, L.
var. crassifolia, Gray.
Celtis Audibertiana, Spach.
Morus rubra, L.
Juglans cinerea, L.
Juglans ———?
Pterocarya fraxinifolia, Spach.
Carya alba, Nutt.
Carya microcarpa, Nutt.
Carya tomentosa, Nutt.
Carya porcina, Nutt.
Carya amara, Nutt.
Quercus Robur. *var.* pedunculata, Willd.
Quercus alba, L.
Quercus macrocarpa, Mich.
var. olivæformis, Gray.
Quercus bicolor, Willd.
Quercus lobata, Nees.

Quercus Prinus, L.
Quercus cinerea, Mich.
Quercus Sonomensis, Benth.
Quercus imbricaria, Mich.
Quercus aquatica, Catesby.
Quercus nigra, L.
Quercus ilicifolia, Wang.
Quercus coccinea, Wang.
var. tinctoria, Gray.
Quercus rubra, L.
Quercus palustris, Du Roi.
Quercus chrysolepis, Liebm.
Quercus densiflora, Hook.
Castanopsis chrysophylla, Alph. DC.
Castanea pumila, Mich.
Corylus Americana, Watt.
Ostrya Virginica, Willd.
Carpinus betulus, L.
Carpinus Americana, Mich.
Betula lenta, L.
Betula alba, *var.* populifolia, Spach.
Betula alba, *var.* urticifolia, Hort.
Alnus glutinosa, Willd.
Alnus serrulata, Ait.
Pinus muricata, Don.
Pinus pungens, Mich.
Pinus inops, Ait.
Pinus mitis, Mich.
Pinus Pinaster, Ait.
var. robusta, Hort.
Pinus resinosa, Ait.
Pinus Sabiana, Dougl.
Pinus ponderosa, Dougl.
Pinus Jeffreyii, Murr.
Pinus Tæda, L.
Pinus rigida, Mill.
Pinus Balfouriana, Murr.
Pinus excelsa, Wall.
Pinus Strobus, L.
Pinus monticola, Dougl.
Pinus Lambertiana, Dougl.
Pinus Torreyana, Parry.
Abies alba, Mich.
Abies orientalis, Poir.
Abies Engelmanni, Parry.
Abies Nordmanniana, Spach.
Abies Sibirica, Ledeb.
Abies amabilis, Lindl.
Abies grandis, Lindl.
Abies concolor, Engelm.
Abies Mertensiana, Lindl.
Abies Pattoniana, Jeff.
Abies Douglasii, Lindl.
Larix Dahurica, Turcz.
Larix leptolepis, Endl.
Cedrus Atlantica, Manetti.
Glyptostrobus heterophyllus, Endl.
Sequoia gigantea, Torr.
Libocedrus decurrens, Torr.
Cupressus torulosa, Don.
Cupressus funebris, Endl.
Cupressus macrocarpa, Hartw.
Thuja gigantea, Nutt.
Thuja plicata, Don.
Biota orientalis, Endl.
Juniperus Sabina, *var.* procumbens, Pursh.
Torreya Californica, Torr.
Smilax rotundifolia, L.
Yucca Treculiana, Carrière.
Yucca rupicola, Schule.
Yucca baccata, Torr.
Yucca filamentosa, L.
Yucca Whipplei, Torr.

No. 14. — *A Record of Trials of various Fertilizers upon the Plain-field of the Bussey Institution.* By F. H. Storer, Professor of Agricultural Chemistry. *Fourth Report. Results obtained in* 1874.

The special purpose of the field experiments of 1874 was to control the results obtained in 1873 upon the plots to which various *mixtures of fertilizers* had been applied. (See pages 116 to 132 of this "Bulletin.")

A large number of trials made with "special" or single fertilizers in the previous years, 1871 and 1872, had shown that the land allotted to the experiments stood in particular need of one kind of plant food (see page 115); and an additional set of trials made in 1873 with mixed fertilizers had served to indicate in a measure the general capabilities of the land. The experiments of 1874 were repetitions of these last, made, as has just been said, for the sake of obtaining a second set of results proper to be contrasted with the first set, and which might serve to confirm them or to disprove them, as the case might be.

The character of the soil and subsoil of the experimental field has been described on page 80. As there explained, the field is covered with a thin layer of loam that rests upon a deep bed of coarse gravel. The position of the plots devoted to the trials now in question will be seen upon the diagram on page 118, at the left and top of the diagram. Each of these plots bore the same kinds of crops in 1874 as in 1873, excepting that no ruta-bagas were sown or planted upon any of the plots in 1874. The experience of the previous years had shown that upon the land of this particular field, the ruta-baga crop is not well suited for the kind of experiments now in question. The line of squares designated EE, Nos. 7, 8, 9 (barley and beans), adjoining section DD, were likewise thrown out of consideration, because that strip of land had been contaminated with dung, as has been explained on page 126.

The same kinds and quantities of fertilizers were applied in 1874 as in 1873 and in precisely the same places, excepting of course the squares that were not to be planted. Compare the remarks on page

117. The mixtures of fertilizers used and the weights of crops obtained will appear from the following tables.

Section E. — Barley. — 1874.

Nos. of the Squares	Kinds and Weights of Fertilizers.	Weights of Crops. Grain.	Straw & Chaff.	Total Product.
1	Neither crop nor manure	. . . .	. . . .	. . . .
2	910 grms. sulphate of ammonia . . 463 " " potash . . . 714 " Bay State superphosphate	3.654	6.846	10.50
3	895 " sulphate of ammonia . . 463 " " potash . . . 714 " Coes's superphosphate . .	3.799	6.951	10.75
4	910 " sulphate of ammonia . . 463 " " potash . . . 833 " Wilson's superphosphate .	3.722	8.028	11.75
5	890 " sulphate of ammonia . . 463 " " potash . . . 400 " Breck's fine bone-meal . .	3.135	6.265	9.40
6	910 " sulphate of ammonia . . 476 " chloride of potassium (83%) 714 " Bay State superphosphate	3.871	6.629	10.50
EE 4	. . . . No manure	0.737	3.012	3.75
7	910 " sulphate of ammonia . . 368 " pearlash . . . . 714 " Bay State superphosphate	3.452	6.798	10.25
8	607 " nitrate of soda . . . . . 476 " chloride of potassium (83%) 1530 " fish-scrap	4.298	8.202	12.50
9	1400 " Peruvian guano . . . . . 400 " sulphate of potash . . .	4.498	8.502	13.00
Y	13650 " ground oyster-shells . . .	0.515	2.985	3.50
X	13650 " oyster-shell lime	1.296	4.454	5.75

Section EE. — Barley. — 1874.

Nos. of the Squares	Kinds and Weights of Fertilizers.	Weights of Crops.		
		Grain.	Straw & Chaff.	Total Product.
1	1164 grms. nitrate of soda . . . . . 463 ,, sulphate of potash . . . 714 ,, Bay State superphosphate	4.846	8.404	13.25
2	1139 ,, nitrate of soda . . . . . 463 ,, sulphate of potash . . . 714 ,, Coe's superphosphate . .	5.311	9.189	14.50
3	1109 ,, nitrate of soda . . . . . 463 ,, sulphate of potash . . . 450 ,, Breck's *coarse* bone-meal .	4.343	7.407	11.75
4	. . . . . No manure	0.737	3.013	3.75
5	1133 ,, nitrate of soda . . . . . 463 ,, sulphate of potash . . . 400 ,, fine bone-meal	3.918	6.832	10.75
6	1164 ,, nitrate of soda . . . . . 476 ,, chloride of potassium (83 per cent) . . . . . 714 ,, Bay State superphosphate	4.194	7.056	11.250

Section EE (South). — Beans. — 1874.

Nos. of the Squares	Kinds and Weights of Fertilizers.	Weights of Crops.		
		Beans.	Stalks, Leaves, & Husks.	Total Product.
1	900 grms. sulphate of ammonia . . 611 ,, ,, potash . . . 865 ,, Bay State superphosphate	4.619	5.045	9.664
2	886 ,, sulphate of ammonia . . 611 ,, ,, potash . . . 865 ,, Coe's superphosphate . .	4.839	5.851	10.690
3	860 ,, sulphate of ammonia . . 611 ,, ,, potash . . . 570 ,, Breck's coarse bone-meal	4.902	6.307	11.209
G 2	3666 ,, wood-ashes . . . . . . 660 ,, pure sulphate of ammonia	3.235	4.110	7.345
4	875 ,, sulphate of ammonia . . 611 ,, ,, potash . . . 500 ,, fine bone-meal	4.742	6.393	11.135
5	. . . . . No manure	0.742	1.940	2.682
6	900 ,, sulphate of ammonia . . 630 ,, chloride of potassium (83 per cent) . . . . . 865 ,, Bay State superphosphate	4.993	6.281	11.274

Section EE (North). — Beans. — 1874.

Nos. of the Squares	Kinds and Weights of Fertilizers.	Weights of Crops.		
		Beans.	Stalks, Leaves, & Husks.	Total Product.
1	1151 grms. nitrate of soda . . . . 611 " sulphate of potash . . 865 " Bay State superphosphate	4.616	6.186	10.802
2	1127 " nitrate of soda . . . . 611 " sulphate of potash . . 865 " Coe's superphosphate .	5.230	5.902	11.132
GG 2	3666 " wood-ashes . . . . . 1212 " nitrate of soda	4.098	4.961	9.059
3	1079 " nitrate of soda . . . . 611 " sulphate of potash . . 570 " Breck's coarse bone-meal	5.122	5.696	10.818
Z	13650 " crushed oyster-shells . . .	0.484	1.151	1.635
4	1115 " nitrate of soda . . . . 611 " sulphate of potash . . 500 " fine bone-meal	5.500	6.174	11.674
5	. . . . . No manure	0.912	1.540	2.452
6	1151 " nitrate of soda . . . . 630 " chloride of potassium (83 per cent) . . . . . 865 " Bay State superphosphate	5.347	5.444	10.791
H 2	3666 " wood-ashes . . . . . 3100 " fish-scrap	4.494	5.840	10.334

Three-Crop Plots. — Barley. — 1874.

Designation of the Squares	Kinds and Weights of Fertilizers.	Weights of Crops.		
		Grain.	Straw & Chaff.	Total Product.
G	2778 grms. wood-ashes . . . . . . 660 " sulphate of ammonia . .	4.690	9.810	14.500
GG	2778 " wood-ashes . . . . . . 1212 " nitrate of soda	4.421	9.579	14.000
H	4444 " wood-ashes . . . . . . 3100 " fish-scrap	5.169	9.831	15.000
J	333 " bone-black . . . . . . 463 " sulphate of potash . . . 1212 " nitrate of soda	2.638	6.612	9.250
JJ	333 " bone-black . . . . . . 463 " sulphate of potash . . . 952 " sulphate of ammonia . .	1.924	4.826	6.750
K	3100 " fish-scrap . . . . 463 " sulphate of potash . . .	4.035	8.465	12.500
KK	333 " bone-black . . . . . . 463 " sulphate of potash . . . 1550 " fish-scrap . . . . 286 " nitrate of soda	2.833	6.167	9.000

Three-Crop Plots. — Beans. — 1874.

Designation of the Squares	Kinds and Weights of Fertilizers.	Weights of Crops.		
		Beans.	Stalks, Leaves, & Husks.	Total Product.
G	3666 grms. wood-ashes; 660 „ sulphate of ammonia	3.235	4.110	7.345
GG	3666 „ wood-ashes; 1212 „ nitrate of soda	4.098	4.961	9.059
H	3666 „ wood-ashes; 3100 „ fish-scrap	4.494	5.840	10.334
Z	13650 „ crushed oyster-shells	0.484	1.151	1.635
J	417 „ bone-black; 611 „ sulphate of potash; 1212 „ nitrate of soda	3.206	3.906	7.112
JJ	417 „ bone-black; 611 „ sulphate of potash; 952 „ sulphate of ammonia	3.005	3.428	6.433
K	3100 „ fish-scrap; 611 „ sulphate of potash	4.649	5.731	10.380
KK	417 „ bone-black; 611 „ sulphate of potash; 1550 „ fish-scrap; 286 „ nitrate of soda	3.765	5.061	8.826

Table showing the Best and the Worst Bean Crops obtained in 1874 by the Use of Mixed Fertilizers.

Names and Nos. of the Squares.	Weights of Bean Seeds.	Names and Nos. of the Squares.	Weights of Bean Straw.	Names and Nos. of the Squares.	Weights of Total Bean Crops.
* N 4	5.500	S 4	6.393	N 4	11.674
N 6	5.347	S 3	6.307	S 6	11.274
N 2	5.230	S 6	6.281	S 3	11.209
N 3	5.122	N 1	6.186	S 4	11.135
S 6	4.993	N 4	6.174	N 2	11.132
S 3	4.902	N 2	5.902	N 3	10.818
S 2	4.839	S 2	5.851	N 1	10.802
S 5	4.742	H	5.840	N 6	10.791
K	4.649	K	5.731	S 2	10.690
S 1	4.619	N 3	5.696	K	10.380
N 1	4.616	N 6	5.444	H	10.334
H	4.494	KK	5.061	S 1	9.664
GG	4.098	S 1	5.045	GG	9.059
KK	3.765	GG	4.961	KK	8.826
G	3.235	G	4.110	G	7.345
J	3.206	J	3.906	J	7.112
JJ	3.005	JJ	3.428	JJ	6.433
N 5	0.912	S 5	1.940	S 5	2.682
S 5	0.742	N 5	1.540	N 5	2.452
Z	0.484	Z	1.151	Z	1.635

* In this table N stands for EE (*north*) and S for EE (*south*).

TABLE SHOWING THE BEST AND THE WORST BARLEY CROPS OBTAINED IN 1874 BY THE USE OF MIXED FERTILIZERS.

Names and Nos. of the Squares.	Weights of Barley Grain.	Names and Nos. of the Squares.	Weights of Barley Straw.	Names and Nos. of the Squares.	Weights of Total Barley Crops.
EE 2	5.311	H	9.831	H	15.00
H	5.169	G	9.810	EE 2	14.50
EE 1	4.846	GG	9.579	G	
G	4.690	EE 2	9.189	GG	14.00
E 9	4.498	E 9	8.502	EE 1	13.25
GG	4.421	K	8.465	E 9	13.00
EE 3	4.343	EE 1	8.404	E 8	12.50
E 8	4.298	E 8	8.202	K	
EE 6	4.194	E 4	8.028	E 4	11.75
K	4.035	EE 3	7.407	EE 3	
EE 5	3.918	EE 6	7.056	EE 6	11.25
E 6	3.871	E 7	6.798	E 3	10.75
E 3	3.799	E 3	6.951	EE 5	
E 4	3.722	E 2	6.846	E 2	10.50
E 2	3.654	EE 5	6.832	E 6	
E 7	3.452	E 6	6.629	E 7	10.25
E 5	3.135	J	6.612	E 5	9.40
KK	2.833	E 5	6.265	J	9.25
J	2.638	KK	6.167	KK	9.00
JJ	1.924	JJ	4.826	JJ	6.75
X	1.296	X	4.454	X	5.75
EE 4	0.737	EE 4	3.013	EE 4	3.75
Y	0.515	Y	2.985	Y	3.50

The season of 1874 was on the whole not unfavorable for the growth of the experimental crops. The abundant rains of the spring and early summer enabled the barley in particular to grow much better this year than in 1873. The beans also did fairly well in spite of the long-continued drought of July, August, and September.

The same disturbing influences that were encountered in 1873 upon a few of the plots, figured at the top of the diagram, due to unfavorable mechanical condition of the soil as mentioned on page 128, were again met with upon those squares. In consequence of these exceptional conditions, the results obtained from the crops grown on the squares marked J, JJ, K, and KK, cannot be put in comparison with those from the other thirty-five squares. These trifling exceptions, which for the rest are easily accounted for, do not in the least detract from the general result of the experiments; namely, that the crops obtained by the use of the mixed fertilizers were excellent, both as compared with those obtained by the use of farm and stable manure, and with regard to the

cost of the ingredients of such mixtures as compared with that of the dung of animals. In respect to the barley crops, for example, a glance at the column headed "Weights of barley grain" in the Table of Best and Worst Crops on page 305, shows that almost every one of the mixtures of a nitrogenous, a potassic, and a phosphoric fertilizer that were employed yielded useful results, as compared with those obtained from barn-yard or stable manure applied at the rate of ten cords to the acre. See beyond page 315, for the results obtained with cow dung and horse dung in 1874, and the general table on page 164 for the results of previous years, squares B 1, and B 2.

A very simple calculation will be sufficient to give an idea of the small cost of employing the mixed fertilizers, as compared with the cost of buying farm or stable manure. Let us take for example the mixture that was applied to square EE 2, which gave the best yield of barley grain in 1874. The crop was at the rate of $39\frac{4}{10}$ bushels to the acre. Since each of the squares was equal to $\frac{1}{162}$ of an acre, there would be needed of the mixture in question for an acre of land: —

Of nitrate of soda . .	1139 grms.	$\times$ 162 =	184.510 kilos. =	406 lbs.
Of sulphate of potash .	463 ,,	$\times$ 162 =	75.000 kilos. =	165 ,,
Of Coe's superphosphate	714 ,,	$\times$ 162 =	115.670 kilos. =	$251\frac{1}{2}$,,

But in the spring of 1874 nitrate of soda could be bought at the rate of $3\frac{3}{4}$ cents per lb., currency; sulphate of potash, containing 54% of real potash, could be bought for less than 3 cents per lb.; and the price of Coe's superphosphate was $50, per ton: whence it appears that the cost per acre of the mixture in question would have been: —

406 lbs. nitrate of soda	@ $0.0375 =	$15.23
165 ,, sulphate of potash	@ 0.03 =	4.95
255 ,, Coe's superphosphate	@ 0.025 =	6.38
		$26.56

I have taken the above mixture at random for this discussion, merely because the barley crop obtained by means of it happened to stand at the head of the list. The mixture is not one to be specially commended. On the contrary, the amount of nitrate of soda contained in it might undoubtedly be reduced at least one-half with advantage. But it is manifest that the prime cost of the mixture, taken exactly as it was used, will compare favorably with that of ten cords of farm or

stable manure of the first quality, let alone the question of transporting the two kinds of materials to the field and of applying them to the land. It is to be observed, moreover, that mixtures of commercial fertilizers equally efficacious with those in the foregoing lists can un-undoubtedly be prepared by the farmer at decidedly lower cost. Thus in the case of the mixture EE 2, barley, that has been specially cited, it would undoubtedly be more advantageous to buy or make a quantity of one of the plain superphosphates, such as have been described on pages 179 and 187, and to use with it as much fish scrap as should contain an amount of nitrogen equal to that in the 255 lbs. of the superphosphate mentioned in the above list. For example, in 325 lbs. of the plain superphosphate, of 10% soluble acid, at $25 per ton, instanced in the note on page 186, and 70 lbs. of fish scrap at $18 per ton, there could be got as much and more than as much of each of the two kinds of plant food, at one quarter less cost. The 325 lbs. of plain superphosphate would cost $4.06 and the 70 lbs. of fish scrap $0.63, equal $4.69 for both.

As was just now said, 400 lbs. of nitrate of soda to the acre is an unnecessarily large application. It would be bad practice to apply so much of the nitrate all at once to any field crop. It is to be noted moreover that a considerable part of whatever amount of the nitrate might be fit and sufficient for the case in hand, could undoubtedly be replaced with advantage by some other kind of nitrogenous manure, such for example as fermented peat, or night soil, or sulphate of ammonia or Peruvian guano, or by a mixture of several or all of these substances. It may even be true that a very large proportion of the nitrogenous food needed by the crop could be supplied as well or possibly better in the form of some of the coarser kinds of nitrogenous fertilizers, such as fish scrap, and flesh meal, and bone meal, than if all the nitrogen were applied in the form of its more active and costly varieties. It is unquestionably desirable that a certain proportion of the latter should be contained in the soil, but it is not improbable that a very small amount of them would be sufficient, provided there was an abundance of the coarser kinds of nitrogenous food at hand. The several kinds of nitrogenized fertilizers differ from one another so much, both with regard to the rapidity of their action and in respect to their retention by the soil, that there can be little doubt that a judicious mixture of two or more of them is better suited to be used in conjunction

with the potassic and phosphatic manures than any single one. In many cases it might even be best to use no nitrate of soda whatsoever in the original mixture of fertilizers that is put upon the land before the seeds are sown; though occasional small doses of the nitrate, applied judiciously from time to time while the crop is growing, could hardly fail to do good. It would of course be impossible to come to any conclusion of general applicability with regard to a question of detail so intricate as this. The composition of the best possible mixture of fertilizers must necessarily vary with the peculiarities of position and the character of each particular farm. A chemist's experiments can do no more than indicate the broad principles upon which the application of fertilizers depends. It belongs to the farmer's art to apply those principles with such intelligence that the wished-for economic result shall be obtained at the least possible cost.

It is to be observed that remarks of analogous character to those just made with regard to the nitrate of soda used upon square EE 2, would apply to almost any of the mixtures of fertilizers that were employed in my experiments. It is not at all probable that the nitrogenous constituents of any one of the mixtures were the best possible, either in respect to quality or to quantity, for the conditions of soil and moisture that obtained in the experiment. It is probably true in general not only for the nitrogenous manures, but to a less extent for the phosphatic and the potassic fertilizers also, as has been urged on page 127, that a certain advantage might be gained when using mixtures of commercial fertilizers, if these mixtures were prepared, not by taking a single kind of fertilizer out of each of the three great classes, as has been done in most of my experiments, but by choosing in an intelligent way several varieties of each of the three special classes. Not only is it likely that a mixture of nitrate of soda and sulphate of ammonia would generally do more good than could be accomplished by the same amount of nitrogen applied in the form of either one of these salts by itself, but a small gain of analogous character may probably be had by using judicious mixtures of sulphate, carbonate, and chloride of potassium rather than any single one of these salts; and the same remark will doubtless apply to the application of bone-meal, or "flesh meal," or composted bone-black to the land, in connection with the use of a true superphosphate. But since either one of these substances, if brought in contact with the superphosphate, would tend to

interfere with the legitimate purpose of the latter which is to diffuse itself through the soil and so disseminate phosphoric acid, neither of them should be put into the original mixture of fertilizers which contains the superphosphate. They may perfectly well be applied to the land after the superphosphate has had time to soak into the soil. As a matter of course, considerations such as these are, in the present state of agricultural knowledge, of theoretical interest rather than of practical importance, since the trouble and expense of handling any considerable variety of manures would in many instances be likely to counterbalance the advantages that might be gained in the manner indicated.

The following calculations, similar to the one given on page 306, show the amounts of fertilizers referred to the acre of land, and their approximate cost, in the cases of mixtures such as were applied to square EE (north) No. 4 of the section devoted to beans, and to squares G and K among the barley crops.*

For an acre of land there would be required of the mixture of fertilizers used upon

Square EE (north) 4, beans.

Of nitrate of soda . .	1115 grms.	× 162 =	180.630 kilos.	= 397⅓ lbs.
Of sulphate of potash	611 ,,	× 162 =	98.982 ,,	= 217¾ ,,
Of bone meal . . .	500 ,,	× 162 =	81.000 ,,	= 178¼ ,,

The cost per acre would have been:—

397⅓ lbs. nitrate of soda	@ $0.0375	=	$14.90
217¾ ,, sulphate of potash	@ 0.03	=	6.53
178¼ ,, bone meal	@ 0.03	=	5.35
			$26.78

Square G, barley.

Of wood-ashes . . .	2778 grms.	× 162 =	450.036 kilos.	= 990 lbs.
,, sulphate of ammonia	660 ,,	× 162 =	106.920 ,,	= 235¼ ,,

The cost per acre would have been:—

990 lbs. (= 20½ bushels †) wood-ashes .	@ $0.30	=	$6.15
235¼ ,, sulphate of ammonia	@ 0.06	=	14.12
			$20.27

* The yield of beans upon EE 4 was at the rate of $32\frac{7}{10}$ bushels to the acre, that of barley on square G was at the rate of 34⅘ bushels, and on square K at the rate of 30 bushels to the acre.

† See page 206, *note*.

Square K barley.

Of fish scrap . . . 3100 grms. $\times$ 162 = 502.200 kilos. = 1105$\frac{4}{5}$ lbs.
,, sulphate of potash 463 ,, $\times$ 162 = 75.000 ,, = 165 ,,

The cost per acre would have been :—

1106 lbs. fish scrap	@	$18.00 per ton	$9.95
165 ,, sulphate of potash . . .	@	0.03	4.95
			$14.90

As was naturally to be expected no one among the various commercial fertilizers employed in these experiments exhibited any noteworthy superiority to its fellows. The mixtures that contained nitrate of soda appear to have given rather better crops on the whole than those which contained sulphate of ammonia. It will be remarked that this result consists with what has been said on 307 as to the advantage of using mixtures of several kinds of nitrogenous fertilizers; for each of the superphosphates that were used in my experiments contained a small quantity of ammonium salts ready formed, besides nitrogenous matters capable of forming ammonia, and the last remark will apply to the bone meals also. The addition of the nitrate of soda had consequently the effect of increasing the resources of the crops. The plants that grew upon those squares of land which received the nitrate manifestly had access to a greater variety of food than their competitors. With this exception, and possibly that of the wood-ashes also, there was no indication that either of the fertilizers served any useful purpose other than to supply the amount of phosphoric acid, or of potash or of nitrogen, which analysis had shown to be contained in it. When used in fit proportion, in conjunction with suitable quantities of the other kinds of plant food, each and all of the materials employed seem to be useful in proportion as they can supply one or another of the above-mentioned desiderata. Since the question of cost was not considered in choosing the fertilizers for these experiments most of the mixtures might be greatly improved upon in that respect, as has been already sugggested on pages 307 and 309. In point of fact, no effort was made to contrive the best possible mixture, even for the experimental field, much less to devise a mixture that should be generally applicable.

Most, if not all, of the mixtures used, were probably very much richer in one or another of the elements of plant food, than they need

have been. It will be seen from the calculations on page 116, that enough of each kind of plant food was taken to have supplied a considerably larger crop than was actually obtained in any one instance. The calculations in question were based upon results that had been obtained in previous years upon a strip of land that proved to be decidedly deeper and richer than the section devoted to the experiments with mixed fertilizers. We are ignorant as to how much more, or how much less of a fertilizer than can be removed from the land, by the largest crop that could possibly grow there, should be added to the land in any given case in order to obtain the maximum crop. The amount needed would vary not only with the chemical composition, and the mechanical texture of the soil, and with the amount of moisture accessible to the crop, but with the seasons also, accordingly as they were more or less wet or dry, warm or cold. It was partly because of this uncertainty, and partly in the hope of obtaining a still larger crop than any that had been got by the use of single fertilizers, that no deduction was made on account of the natural strength of the land from the data which served as the basis of the calculations on page 116. The argument there developed, would plainly have been more logical if the yield of the squares, numbered "5," that had not received any manure, had been subtracted from the amounts harvested on the squares that yielded the best crops, before making the calculations. In point of fact, experience has shown that the argument and my expectations were both pitched too high. The crops obtained by the use of mixed fertilizers in 1873 and 1874, and those obtained by means of heavy dressings of dung and of wood-ashes in 1871, '72, '73, and '74, show very clearly that the power or ability of the land of the experimental field to yield crops is limited to the amount of five or six kilogrammes of grain, whether of barley or beans and the corresponding amount of straw; that is to say, under the conditions of climate and tillage that have obtained in these years. Although this subject has been discussed quite fully already on page 129, it should again be said that in view of the poor character of the surface soil of the experimental field, of the great distance of that soil from the ground water (see page 80), and of the coarseness of the gravel upon which the soil rests, it may fairly be held, that the crops actually obtained in 1874, were in general as good or very nearly as good as could have been obtained from this particular soil and field by any process of mere

manuring, no matter how diverse the kinds of fertilizers or how abundant their quantity. By resorting to processes of tillage, such as trenching or subsoil plowing, by which the soil could be deepened and its power of lifting, of absorbing, and of holding water increased, or by irrigating the land with water outright, it would of course be possible to bring the soil into such condition that it might bear larger crops and utilize more manure. Something might perhaps be done by judicious mulching also. Thus, in view of the mulching property of stable manure, it is not unlikely that a certain amount of such manure used in conjunction with a potassic fertilizer, or with a mixture of potassic, phosphatic, and nitrogenous fertilizers might have yielded a somewhat better crop in the dry seasons of 1873 and 1874 than either of the mixtures of fertilizers that were actually used.

The inutility of manuring the soil of the field so heavily as has been done with the mixtures above described is still further illustrated by the results of a blunder made upon plot H in the spring of 1873. My original intention was to grow ruta-bagas upon the square now marked H 1 on the diagram, and the comparatively large amount of mixed fertilizers actually put upon that square was meant to support a ruta-baga crop. But, through inadvertence, barley was sown upon the square now marked 1, and ruta-bagas were sown upon the square now marked 3, that had been manured for barley. Thus it happened that the barley crop that grew upon square H received 4444 grms. of wood-ashes instead of 2778 grms., as was intended. The error having once been committed, it was thought best to persist in it. Hence, the square H, barley, got the same excessive dose of wood-ashes in 1874 that it had received in 1873. It is true that the crop obtained from this over-manured square was one of the best, both in 1873 and in 1874; but it was nevertheless no better on the whole than the crop from square G, which received an analogous mixture of fertilizers, in much smaller quantity. It will be noticed on the other hand (page 123), that the comparatively small quantity of fertilizers put upon the ruta-baga square H in 1873 failed to yield so large a crop as was obtained from square G and square GG. Only about half as much potash as was intended was really put upon the ruta-baga square H in 1873.

As illustrating the merits of wood-ashes and of fish scrap, it may be remarked, in passing, that the heavy dressing of manure applied to

square II, barley, really cost comparatively little money. There would be needed for an acre of land, of the mixture used on square II, barley: —

Of wood ashes . .	4444 grms. $\times$ 162 =	719.927 kilos. =	$1583\frac{4}{5}$ lbs.
,, fish scrap . . .	3100 ,, $\times$ 162 =	502.200 ,, =	$1105\frac{4}{5}$,,

The cost per acre would have been: —

1584 lbs. (= 33 bushels) wood-ashes . .	@ \$0.30 =	\$9.90
1106 ,, fish scrap	@ 18.00 per ton =	9.95
		\$19.85

The meagre crops yielded by squares X, Y, and Z, that were dressed with oyster-shell lime, or with crushed oyster shells, show how little permanent significance carbonate of lime has by itself upon a soil so poor and dry as this.

It is to be regretted that the soil on parts of the squares (J, JJ, K, and KK.) allotted to the experiments with bone-black should have been exceptionally hard and unsuited for the growth of plants, as has been mentioned on page 128. For my own part I have never had any reason to doubt that in the great majority of cases it would be much better practice to subject spent bone-black to fermentation in a heap of composted peat than to apply it directly to dry land in its crude condition. A conspicuous method of French agriculture that has been alluded to on page 269, seems to point very clearly to the conclusion that spent bone-black might be used with advantage by our New England farmers as a component of their compost heaps. Some experiments that I have myself made on a small scale under glass point in the same direction. But I would nevertheless have been glad to test the action of the crude material (spent bone-black) fairly upon the field, as contrasted with that of the other sources of phosphoric acid. The fact that the experimental crops grew well enough in 1874, as in 1873, upon parts of each of the squares that had been dressed with the spent bone-black showed very clearly that the land was in bad condition, and that the manures applied to it were not in a position where they could be fairly tested.

Trials of Single Fertilizers.

The experiments with farm — and with stable — manure and a few of the trials with single fertilizers, such as had been made in 1871, 1872,

and 1873 were repeated in 1874, as will appear from the following table. All of these trials were precise repetitions of those of the previous years. They were made for the sake of testing once more the effect of persistent cropping in the special cases to which they refer. Among the large number of experiments with single fertilizers that had been made in the preceding years, the few kinds enumerated in the table seemed to be the only ones whose repetition promised to be of sufficient interest to justify the trouble of it.

The good effects produced by the potassic fertilizers, especially by the heavy dressings applied to squares BB 6 and BB 7, are again remarkable, as they had been in the previous years, though the crops obtained by the repeated use of this single kind of plant food are naturally smaller than those from the squares that had been treated with dung or with a mixture of fertilizers, and so supplied with all three of the important kinds of plant food. So, too, the crops from square BB 4 that during the four consecutive years had received an enormously heavy dressing of wood-ashes, are surprisingly good. It appears from the analyses that have been reported on page 193, that the wood-ashes used in these experiments contained in every bushel about $3\frac{1}{4}$ lbs. of real potash and from $1\frac{1}{2}$ to $1\frac{3}{4}$ lbs. of phosphoric acid. Hence there was applied every year to square BB 4, some ten or twelve times as much potash, and about twice as much phosphoric acid as would have been sufficient, according to the estimates on page 116, to supply crops even larger than any that were ever obtained from this square. The ashes probably contained no nitrogen, or as good as none. But, thanks no doubt to the alkaline property of the ashes, the nitrogen in the humus of the soil was made available by them for the crops. As has been stated on page 258, a sample of the soil of the plain field, collected in 1871 was found to contain rather less than a quarter of one per cent of nitrogen. It may be admitted, moreover, that upon each of the squares devoted to the experiments there were as many as 16,000 lbs. of dry loam, such as that in which analysis had indicated 0.24% of nitrogen. Hence there must have been as much as 38 lbs., or more than 17,000 grammes of nitrogen in the soil of BB 4 at the beginning of the series of experiments; but it will be seen on page 116, that the highest estimate of the amount of nitrogen needed by either kind of crop is less than 600 grammes per year.

The squares dressed with cow dung and with horse dung, undoubtedly

Section B. — Kinds and Weights of Crops, in Kilogrammes. 1874.

Weights of Fertilizers, in Grammes.	Nos. of the Squares.	Barley.			Beans.		
		Grain.	Straw and Chaff.	Total Product.	Beans.	Stalks, Leaves, and Husks.	Total Product.
8 cubic feet of cow-manure from a milk-man's stable	1	3.842	8.658	12.500	5.685	7.279	12.964
8 cubic feet of long horse-manure from a city stable	2	4.141	9.859	14.000	5.680	7.359	13.039
4095 grms. of wood-ashes	4	1.832	4.918	6.750	3.825	5.213	9.038
No manure	5	0.905	2.845	3.750	0.208	0.818	1.026
307 grms. of pearlash	6	1.616	4.134	5.750	2.084	3.143	5.227
307 grms. of sulphate of potash	7	1.234	3.516	4.750	2.561	3.219	5.780

Section BB. — Kinds and Weights of Crops. 1874.

Weights of Fertilizers, in Grammes.	Nos. of the Squares.	Grain.	Straw and Chaff.	Total Product.	Beans.	Stalks, Leaves, and Husks.	Total Product.
8 cubic feet of cow-manure from a milk-man's stable	1	5.606	11.644	17.250	4.612	5.882	10.494
8 cubic feet of long horse-manure from a city stable	2	4.579	9.671	14.250	6.023	7.588	13.611
3 bushels of wood-ashes	4	4.774	10.476	15.250	5.205	7.664	12.869
No manure	5	1.302	3.448	4.750	0.493	0.926	1.419
1336 grms. pearlash	6	2.254	4.496	6.750	3.310	4.805	8.115
2267 grms. of sulphate of potash	7	1.457	3.543	5.000	3.359	4.085	7.444

received much larger quantities of plant food than the crops could use. Thus, horse manure sent from stables in New York city into Connecticut by railroad was found by Prof. Johnson * to weigh 35 lbs. per cubic foot and to contain (among other things) 0.53% of nitrogen, 0.51% of potash; 0.41% of phosphoric acid; and 75% of water. If it be admitted, for the sake of the argument, that the stable manure applied to squares B 2 and BB 2 was of similar weight and composition to the sample examined by Johnson, then each of these squares received in the 280 lbs., or $127\frac{1}{3}$ kilos., of the manure that were applied to it 675 grammes of nitrogen, 649 grammes of potash and 522 grammes of phosphoric acid; that is to say, vastly more of each of these substances than was applied in the mixtures of commercial fertilizers, or than there was any real need of, to judge by the data given on page 116 or by the crops that were actually harvested from the squares that received the horse dung.

The same remark will apply to the squares that were dressed with cow manure. Fresh cow dung from West Cornwall, Conn., as examined by Prof. Johnson,* weighed 63 lbs. to the cubic foot and contained 0.38% of nitrogen; 0.36% of potash; 0.16% of phosphoric acid, and 85% of water. Hence, if the dung applied to squares B 1 and BB 1 was of similar weight and composition to Johnson's sample, each of these squares must have received 504 lbs., or 229 kilos., of the dung, containing 870 grammes of nitrogen, 825 grammes of potash, and 367 grammes of phosphoric acid.

It is hard to believe that the application to dry soils of such enormous quantities of plant food as these analyses indicate can be either judicious or economical. It would seem to be far more reasonable to use moderate quantities of stable manure in conjunction with artificial fertilizers, than to apply large quantities of the dung by itself. There are undoubtedly certain valuable qualities that are peculiar to stable manure, notably its power of diffusing nitrogen compounds in the soil, as was urged on page 131, and of loosening and mulching the land. It is important of course that these peculiarities should be clearly recognized and made the most of; but, in so far as concerns the carrying of potash and of phosphoric acid to the land, it does not appear that the dung of animals has any special merit. In this respect it is probable

* Seventh Report Sec. Connecticut Board of Agriculture, 1873, page 350. The dung in question was well-nigh free from any admixture of straw.

that dung is but little if any better as a manure, than the plants from which it was formed; and it is probably true that, in the vast majority of cases, the real efficiency of barn-yard manure would be increased by the addition of a certain proportion of soluble potassic and nitrogenous fertilizers and by dressing the land beforehand with a true superphosphate. Just as the mulching and diffusive power of the stable manure would tend to increase the efficiency of a mixture of artificial fertilizers, as was urged on page 312, so the ready solubility and diffusive power of the latter, — their so-called activity, — would enable the crop to use the constituents of the dung more fully than would otherwise be possible. There is manifestly wide room for observation and for the exercise of judgment in adapting such mixtures to the conditions and requirements not only of each special farm, but of each particular soil and crop and field.

For the sake of ready comparison, the amounts of "grain" and of "total product" that have been harvested during each of the four years from the barley and the bean squares now specially in question are given upon the next page in tabular form. It is to be remembered that the barley crops of 1873 were as good as ruined by the severe drought that prevailed throughout the early part of that year.

TABLE SHOWING SOME OF THE CROPS FROM **Sections B** AND **BB** DURING FOUR CONSECUTIVE YEARS.

Kinds of Manures.	Nos. of the Squares.	Year in which the Exp. was made.	Barley. Weights of Grain.	Barley. Weights of Total Barley Crops.	Beans. Weights of Bean Seeds.	Beans. Weights of Total Bean Crops.
Farm manure, or cow-dung	B 1	1871	2.570	21.100	7.380	16.000
		1872	1.650	9.250	6.410	12.750
		1873	0.285	3.250	4.640	12.020
		1874	3.842	12.500	5.685	12.964
Ditto	BB 1	1871	5.145	23.400	5.065	15.100
		1872	2.760	12.650	4.460	8.250
		1873	0.672	4.250	4.069	11.541
		1874	5.606	17.250	4.612	10.494
Strawy horse-manure	B 2	1871	2.590	18.750	9.090	18.150
		1872	0.970	5.000	5.600	7.25+
		1873	0.265	2.250	6.112	15.375
		1874	4.141	14.000	5.680	13.039
Ditto	BB 2	1871	4.000	19.850	7.550	16.850
		1872	2.410	10.350	4.580	8.000
		1873	0.461	3.000	5.636	13.432
		1874	4.579	14.250	6.023	13.611
Heavy wood-ashes	BB 4	1871	4.725	20.100	8.230	15.500
		1872	2.860	13.000	6.320	11.000
		1873	0.770	3.750	6.610	16.587
		1874	4.774	15.250	5.205	12.869
Light wood-ashes	B 4	1871	1.570	8.750	4.740	10.550
		1872	0.800	5.000	5.440	9.100
		1873	0.259	1.750	4.734	12.253
		1874	1.832	6.750	3.825	9.038
Heavy sulphate of potash	BB 7	1871	4.630	18.500	7.230	14.500
		1872	2.650	10.850	5.760	9.500
		1873	0.496	2.750	4.322	10.770
		1874	1.457	5.000	3.359	7.444
Light sulphate of potash	B 7	1871	1.035	5.400	3.675	9.250
		1872	1.240	3.850	4.660	7.600
		1873	0.202	1.250	4.612	8.611
		1874	1.234	4.750	2.561	5.780
Heavy carbonate of potash	BB 6	1871	2.095	9.000	6.605	13.700
		1872	2.110	7.000	5.190	8.800
		1873	0.590	3.000	4.561	10.489
		1874	2.254	6.750	3.310	8.115
Light carbonate of potash	B 6	1871	2.080	9.750	4.550	9.400
		1872	1.760	9.000	4.050	6.650
		1873	0.575	3.000	4.021	9.636
		1874	1.616	5.750	2.084	5.227
No manure; rather worse land than square BB 5	B 5	1871	1.120	5.000	0.565	3.750
		1872	0.750	4.250	0.660	1.650
		1873	0.227	1.750	0.349	3.409
		1874	0.905	3.750	0.208	1.026
No manure; rather better land than square B 5	BB 5	1871	1.550	6.500	2.450	6.800
		1872	1.310	5.850	1.580	3.400
		1873	0.202	1.250	0.831	2.798
		1874	1.302	4.750	0.493	1.419

No. 15. — *The Potato Rot.* By W. G. Farlow, Assistant Professor of Botany in Harvard University.

While it has been known to botanists for more than twenty-five years that the potato rot is caused by the growth of a minute fungus, called by Montagne, who first described it, *Botrytis*, by later writers *Peronospora infestans*, there are certain points in the life history of this fungus which have not yet been cleared up, — points which, if answered, might suggest to the farmer a means of avoiding, to some extent, the occurrence in its worst forms of this unfortunately too common epidemic. The object of the present paper is to give to the agriculturalist a statement of the condition of our knowledge of the habits of the Peronospora infestans, its germination, growth, propagation, &c., to state the questions which science has still to answer, and the direction in which investigations will have to be made in the future, and, finally, as far as is possible, to apply the knowledge which a microscopic study of the Peronospora has given us to a consideration of the means of avoiding or diminishing the rot.

It might, perhaps, seem superfluous to recount the symptoms by which the disease, the rot, manifests itself, so familiar are they to the persons into whose hands this paper is likely to fall. It makes its appearance in midsummer in our latitude, usually about the first of August, sometimes earlier, oftener a little later. At times its advent is so sudden that, within a few hours, the potato fields change from green to brown and black, and the plants which, in the morning, gave promise of an abundant crop, before night present a mass of decaying vegetation, in which are involved not only the leaves and stems, but, also, the tubers. The disease occurred in this violent form in 1842, and again in 1845, and spread over a good part of the United States and the British Provinces, and also destroyed the crop in Great Britain, Ireland, Belgium, and parts of Germany and France. The greatest injury was done in Nova Scotia, New Brunswick, and Ireland, owing to the fact that, in these countries, the potato was the principal crop. Since 1845, the disease has recurred, but never with such violence, although during the last year, 1874, the damage was considerable. Although public attention was first called to the

rot in 1842, it is not at all likely that it then appeared for the first time, but we must suppose that some of the vaguely described epidemics of the last century were of the same nature.

It is with such sudden and violent outbreaks as those of 1842 and 1845, that in the public mind the potato rot is associated. As a rule, however, the disease is of a milder type. Instead of a sudden destruction of the crop, there appear on the leaves and stem brown spots, which gradually extend. After a while, certain plants are found to be rotting, and this process may keep on until a whole field is involved. This case, as far as the farmer is concerned, is very different from the other, inasmuch as, having seen that some plants are rotting, he can then, by harvesting the rest, save a portion of the crop.

In whichever form the rot occurs, it makes its appearance always about the same time, as before mentioned, about the first of August, and always in damp weather. There is no case reported as occurring in a dry season, and a moist condition of the atmosphere is absolutely necessary to its production to any decided extent. Damp, muggy weather is, however, quite as favorable to its development as heavy rains.

As was just remarked, the disease is first recognized by the brown spots appearing on the leaves. What is the structure of these brown spots? But, first, a word on the normal structure of the potato leaf. If we make a section through a healthy green leaf, and examine it with a moderately high power of the microscope, we find that it is composed of a number of cells or sacs packed together in an orderly sort of confusion, if one can say so. On the upper and lower surfaces, respectively, we find the cells arranged in a single layer, known as the *epidermis*. Here the cells are almost colorless, and shaped like flat tiles or the bricks of a sidewalk. On the upper surface they are nearly continuous; on the lower we find certain breaks, known as *breathing-pores*, where there is a communication between the internal part of the leaf and the external air. The internal cells are much more nearly spherical or ovoidal than the external, and are full of roundish green bodies which are called *chlorophyl-grains*. It is these bodies, seen in mass, which make the whole leaf look green to the naked eye, although the outside epidermis cells are colorless. The internal cells are packed tolerably closely together near the upper surface of the leaf, but below they are arranged loosely, so that there

are a good many air spaces, some of which connect with the external air by means of the breathing-pores. There are also in certain parts of the leaf bundles of vessels or very long cells with thickened walls marked with rings, spirals, &c.; but, in the present article, we need not consider them.

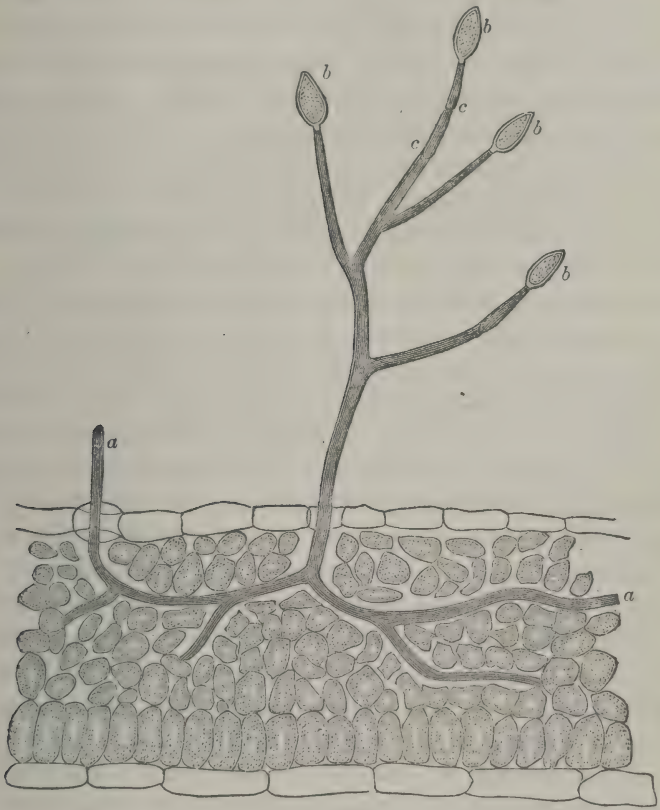


Fig. 1.

Suppose, now, we make a section through one of the brown spots on the leaf of a plant affected by the rot. We notice that the cells are of about the same shape as in the healthy leaf, but the chlorophyl-grains have lost their bright green color and are, in some places, evidently becoming disintegrated. We notice, also, something which was not seen at all in the healthy leaf. A number of branching threads, represented in Fig. 1, *a*, *a*, are seen running between the proper cells

of the leaf previously described, and pressing against them. These threads are cylindrical in shape, branch in all directions, and are only rarely divided by cross partitions. They are of a brownish color, and filled with a granular mass in which we never find any chlorophyl-grains. If we apply iodine and sulphuric acid we shall find that the wall of the filament does not turn blue, or, at least, not very decidedly so, whereas the walls of the true leaf cells become a bright blue. This blue color is owing to the presence of *cellulose*, a substance allied to starch, and composed of oxygen, hydrogen, and carbon. The contents of the leaf cells, known as the *protoplasm*, the outer and thicker layer of which has been called the *primordial utricle*, contain, in addition, nitrogen. The contents of the mycelial threads, except that chlorophyl-grains are wanting, are essentially similar to those of the leaf cells.

We need not limit our observations to the brown spots on the leaves. If we examine the adjacent green part, or even the stalk, we shall find the same filaments running between the cells, the only difference between the two cases being that, in the latter, the leaf-cells have a fresher look, and the chlorophyl-grains are still green. Sometimes little projections are given off by the filaments, which depress the walls of the adjacent cells, or even perforate them, making their way into the interior. Such projections, however, are not common, either in the leaf or stalk. These filaments are what is known to botanists as the *mycelium*, or vegetative threads of a fungus, the Peronospora infestans; and, if we examine any potato plant affected by the rot, even before any spots have appeared on the leaves, we shall always find these threads in the leaves, stem, and, in fact, nearly the whole plant.

It is a well known fact in vegetable physiology that the assimilation of food is done by cells containing chlorophyl; and, since the mycelium contains no chlorophyl, the Peronospora must steal its food from the already assimilated material in the potato cells. It does this by direct absorption. The leaf-cells are capable of doing a certain amount of extra work, and can support not only themselves, but a given amount of the Peronospora also. Accordingly, we see some leaves green and apparently healthy, which, on microscopic examination, are found to contain some of the mycelium of the Peronospora. But there is a limit to the capacity of the green cells for work, and, when the parasite has grown to such an extent as to demand too much of them, they

die overworked, or, in other words, starved out. Such is the process which has taken place in the black spots on the leaf. Here the parasite has increased to such an extent as to destroy the proper tissue of the leaf, while, in the adjacent green parts, although the mycelium is present, it is not in such quantity as to overcome the assimilating power of the leaf-cells. It is an important fact that the relative activity of the latter and of the mycelium varies with the temperature and moisture of the surrounding atmosphere. The Peronospora is much more easily affected by moisture than the potato plant itself. So long as the air is dry, the mycelium grows but slowly, while, unless the dryness is excessive, the potato leaves can do their work very well. But suppose the temperature to keep equally warm, and the atmosphere to become very damp, then the absorbing power of the mycelium is very much increased, while the assimilating power of the leaf-cells is little altered. Thus it happens that a sudden change from dry weather to moist will cause the mycelium to increase so very much beyond the power of the potato plant to support it, that, in the struggle for existence, the latter blackens and dies. Once in a given plant, then, we see how the Peronospora can destroy it; but the question arises, How does it get in?

So far, we have spoken only of the mycelium as found in the leaf; but, as the disease advances, it is found in any part of the plant, even the tubers, and the description given of it in the leaf will answer for it in any part of the plant, except that, in the tubers, it is generally a little larger and furnished with more numerous projections than elsewhere. When the disease has arrived at a certain point, viz., just about the time of the appearance of the spots on the leaves, these mycelial threads make their way into the air, and, taking the easiest course for this, they generally grow through the breathing-pores. As has already been observed, the breathing-pores are more numerous on the under surface of the leaves than anywhere else; and it is on this part of the plant that we most easily recognize the change. To the naked eye it appears like a slight frost on the leaf, and, after the spots have begun to appear, we generally find around them, on the under surface of the leaf, a ring of frost work, very delicate, however. Under the microscope we have the appearance presented in Fig. 1, where, for convenience in printing, the leaf has been inverted, and what appears to be the upper surface is, in reality, the lower. On the left hand we

see a filament which is just making its way through a breathing-pore, and, in the centre, an older one, which will be described presently. Within the leaf the mycelium is seen branching amongst the cells. Once in the air, free from the tissue of the leaf, the mycelium bears the reproductive bodies or *spores*,* — the term generally given to all bodies in the lower plants which take the place of seeds in the higher plants, by which the fungus, or, what is the same thing in this case, the disease is conveyed to other plants. The threads either grow straight forward or branch, and, at the tip or tips, swell until they attain the shape shown in Fig. 1, *b*. They are cut off from the rest of the mycelium by a cross partition, and, when ripe, easily fall from their attachments. It must be noticed that these spores are *asexual;* that is, produced directly from the mycelial threads without the intervention of any sexual organs, such as are known by the names of *antheridia* and *oögonia*, terms which imply a functional resemblance to the anthers and ovaries of higher plants. Generally, just before the spore has fallen from the tip, the mycelium immediately below grows out on one side upwards, and again bears a spore at its end. In this way, the first spore is pushed over, so that, if it has not already fallen off, — which it is very likely to have done, — it looks as though it had grown from the side instead of the tip; and spore number two, which is really lateral, appears terminal. The nodes on the mycelium, represented in Fig. 1, *c*, show where previously formed spores have dropped off, the first having been the lowest down.

* The term *spore* applied to fungi is extremely vague, since it denotes all the reproductive bodies, without regard to their origin or structure. The most natural division of spores seems to be that of many continental mycologists into oöspores, or those produced by some sexual action, and asexual spores. The term *sporidium* does not seem to me to be advisable, inasmuch as it denotes bodies of quite different origin; for example, in Mucor the so-called sporidia are asexual, while in the Perisporiaceæ the asci are products of a growth following a sexual action. The immense variety of asexual spores in fungi prevents us from using a single word which will apply equally well to all cases. The term *conidia* is now quite generally adopted to express collectively the asexual spores. The body containing spores is known as a *sporangium*. In the case of Peronospora infestans, we are at a loss to know what term to apply to the aerial fruit shown in Fig. 1, *b*. If the germination always took place as in Fig. 2, *b*, we should have no hesitation in calling the body a spore. If it always germinated by zoöspores, as in Fig. 2, *c*, we should call it a *sporangium* or *zoosporangium*. The question is merely a verbal one, however. The facts in the case are easily understood.

In nature, the asexual spores appear principally on the under surface of the leaf and on the stalk, but, wherever the tissue of the plant is cut so that the enclosed mycelium readily reaches the air, we may have them produced. This may be shown, artificially, by making a section of a tuber affected by the rot, and placing it in a moist place. In a short time the cut surface will be covered with a layer, like cotton wool, which, on examination by the microscope, will be found to consist of mycelium and spores, precisely like those in Fig. 1, only much more luxuriant. It is only in the air, however, that the asexual spores are produced, never in the substance of the potato. When, however, the potato tuber has so far rotted that there are cavities in the interior, the spores may be produced in the cavities.

As just remarked, the spores easily drop off, and, if we bear in mind that the greater part of them are on the under surface of the leaf, they naturally fall upon the leaves below and to the ground. They may also be blown away to a distance. They are easily recognized by their oval shape, somewhat pointed at one end, and by their having a very short stalk at the blunt end, as in Fig. 2, *a*. If they fall upon a moist surface, no matter of what kind, they begin in a few hours, sometimes even in the course of a single hour, to germinate. The way in which they do this varies in different cases. The more common mode is as follows: The contents of the spore roll themselves up into several different masses which collect at the small end, and, finally, burst through, as is shown in Fig. 2, *c*, leaving the empty shell behind. Fig. 2, *d*, gives a more highly magnified view of one of the bodies represented in *c*. They move rapidly about over the moist surface on which we have supposed them to fall for from fifteen minutes to half an hour, the motion growing constantly slower.

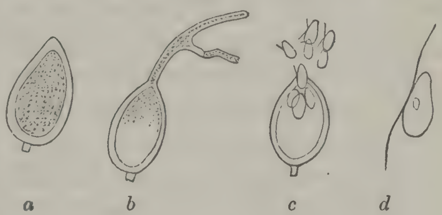


Fig. 2.

This motion is brought about by the vibration of two hair-like bodies, called *cilia*, attached as shown in the figure. From the fact that they move about like animalcules they are called *zoöspores*. The number produced in each spore is generally from six to fifteen. At the end of about half an hour, having come to rest, the cilia disappear, and the

bodies elongate at one end into a tube, which soon begins to branch just like the original Peronospora mycelium. The germination by means of zoöspores, although the most frequent, is not the only method. Sometimes, the contents of the spore are discharged in one mass, and from this mass zoöspores are produced as before. A third and more simple way is shown in Fig. 2, *b*. Here the germinal tube grows directly from the smaller end of the spore without the intervention of zoöspores. It is not very well understood why the spores of the same fungus should be subject to such variations in their mode of germinating, but it would seem to depend partly on the influence of light; the production of zoöspores proceeding more favorably in the dark, whereas the direct production of a germinal tube takes place more frequently in the light. I have, however, repeatedly sown spores of Peronospora infestans in watch glasses, and both modes of germination were seen in the same watch glass. The germination by zoöspores is the more dangerous, of course, because each spore can then reproduce from six to fifteen new Peronospora plants instead of only one, and those who are fond of figures can easily make most appalling calculations to show what would be the result if all these germinal tubes grew.

Fortunately, the circumstances under which the tubes will grow are limited, as the group of fungi to which the Peronospora infestans is, or until recently has been, supposed, at least, to belong, will grow only on a single species, or a few nearly related species of plants. Consequently, although the Peronospora spores will germinate anywhere if there is only moisture and warmth, the germinal tubes will all die unless the spores have fallen upon, or near, some potato plant, or some species of plant botanically closely allied. Some spores, of course, when ripe, easily fall upon, or are carried by the wind to other potatoes, as yet unaffected by the rot. Others fall to the ground and germinate there, and seem to be able, without great trouble, to penetrate to the tubers. De Bary found the ground under infected plants full of the germinating spores. If the germinal tubes come in contact with a potato leaf, stalk, or tuber, they push their way directly through the epidermis, without, apparently, being obliged to enter by the breathing-pores. Once inside, the mycelium grows at the expense of the potato cells through all parts of the plant, as we have already seen. The potato rot fungus will grow, so far as we yet absolutely

know, only on certain Solanaceæ, including the tomato. It does not, however, succeed well on the latter. The germinating power of the spores lasts for several weeks, but they do not germinate after a winter's exposure.

In brief, then, the mycelium of the Peronospora infestans, after making its way through the stem, leaves, and root of the potato, passes through the breathing-pores into the air, and there produces asexual spores. These falling on the leaves of healthy plants, or reaching the tubers in the ground, spread the disease from plant to plant with greater or less rapidity, depending on the weather, until the frost destroys all except the tubers which have been gathered by the farmer. The question arises, How is the disease propagated from year to year? Certainly not by the mycelium in the dead leaves and stalks, which cannot survive the cold of winter, or by the asexual spores which have been described. One way, and the only one, so far as has yet been proved, is by means of the mycelium in the tubers which have been gathered in the fall and planted the next spring. Of course, very rotten potatoes are not harvested, neither are those known to be rotten planted in the spring; but, nevertheless, as can be proved by microscopic examination, a certain amount of mycelium can often be detected in potatoes which appear sound, and it only needs a sufficiently damp season for it to produce disastrous results.

The question whether the disease may not also be propagated from year to year in some way different from that just mentioned, requires farther consideration; for, although such may be the case, we are not, as yet, in possession of a sufficient number of facts to warrant us in speaking with certainty, and it must be regarded as an open question which botanists are trying to answer. There are, in the first place, theoretical grounds in favor of such a belief. The bodies called spores in fungi are some of them asexual, like those which we have seen in the potato rot, and others are the result of some sexual action, and are known as *oöspores*. Any species of fungus may have both sexual and asexual spores, and, perhaps, several different kinds of the latter. Also, when a fungus is parasitic on different kinds of plants, the mycelium may, on one kind, bear only asexual, on another only sexual, spores, or the two may be borne together. Although, in the case of a great many fungi, the oöspores have never been found, all modern research renders it extremely probable that they always exist, and we

do not, at the present day, consider our knowledge of a fungus complete until we have found the oöspores, and the organs which have produced them, the antheridia and oögonia. In the case of Peronospora infestans, the oöspores have never been discovered, and, consequently, the true systematic position of this fungus is uncertain. Judging from the mycelium and the asexual spores, it seems nearly related to Peronospora (Botrytis) gangliformis, Berk, and the true Peronosporæ, where both oöspores and asexual spores are known. Reasoning by analogy, we should expect to find the oöspores of the so-called Peronospora infestans like those of Peronospora gangliformis, which causes the mould in lettuce, unfortunately common in this vicinity, and the source of considerable loss to market gardeners. Let us examine this plant, in passing, as it may help to a clearer conception of the potato disease.

The lettuce mould, like the potato rot, sends its mycelium through the foster plant, until it finally breaks through the breathing-pores and bears its asexual spores in the air, as shown in Fig. 3, which represents a portion of the epidermis of the lettuce, with a breathing-pore through which the mycelium has grown. The spores are more decidedly oval than in the potato rot, and are arranged star-fashion on the swollen tips of the mycelium. They germinate by direct germinal tubes, in the way shown in Fig. 2, *b*, and these penetrate into the interior of the common groundsel (Senecio vulgaris), chiccory, and sow-thistle, as well as of different species of lettuce. In the substance of the leaves of some of these plants, especially the

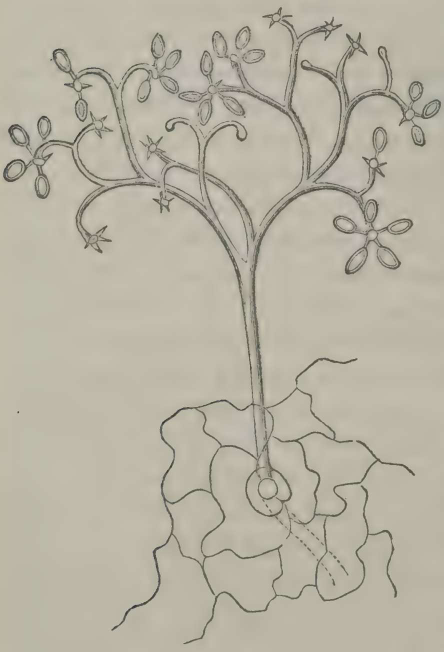


Fig. 3.

groundsel, the oöspores of Peronospora gangliformis are produced. These are small globular bodies, with a thicker outer covering than the asexual spores have. They are produced in the following way: The mycelium swells up into a sac or oögonium, which is cut off from the rest of the mycelium by a cross partition, shown in Fig. 4, *o*; and the protoplasmic mass, *s*, rolls itself up into a ball at the centre, which is to become the spore. The antheridium, or male organ, is formed by a similar swelling at the end of another filament, which applies itself to the surface of the oögonium as shown at Fig. 4, *a*. The sexual act consists in the growth of a small tube, called the *pollinodium*, from its supposed resemblance to a pollen tube, which penetrates to the protoplasmic mass in the centre of the oögonium. As a result of this contact, a wall of cellulose is formed around the mass which grows into the spore. These sexual spores, buried in the leaf, are

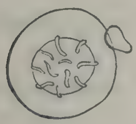


Fig. 5.

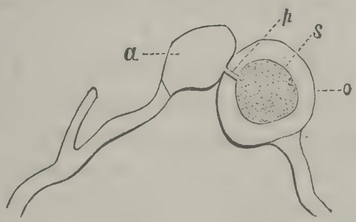


Fig. 4.

much tougher than the asexual, and can endure the cold of winter and drought of summer to a much greater degree. When the lettuce leaf dies, the proper leaf cells decay, leaving the oöspores behind, which then, after the lapse of some weeks, begin to germinate.

Another familiar case of a fungus having both sexual and asexual spores is seen in the Cystopus candidus or white mould on cruciferous plants, mustard, radishes, cabbages, &c. The asexual spores are here again on the surface of the leaf or stem, while the sexual are buried in the tissue. The former are not single as in Peronospora infestans and gangliformis, but in rows packed closely together, which, to the naked eye, appear like white spots on the leaves and stems. The oöspores are produced in the same manner as those of Peronospora gangliformis, and differ from them in having certain brown wavy ridges running over them, as in Fig. 5. These oöspores are only set free by the decaying of the leaf substance around them, and take a very

much longer time to germinate than the asexual spores. Analogy, then on the supposition that the potato rot is a true Peronospora, would lead us to search for the oöspores in the substance, not on the surface, of the potato or some allied plant. The potato, however, has been so well searched by different observers, that, if the oöspores are really there, it seems hardly credible that they should for so long a time have escaped observation. The more probable supposition would be that the disease, as well as the potato, was imported from Peru, and that, in that country, the Peronospora lives upon different species of Solanum, of which there are a good many that inhabit Peru, and that, although when growing on the potato only asexual spores are produced, yet, on other species of Solanum, oöspores as well are found. If this last supposed species of Solanum has not yet been introduced into Europe or North America, that is a sufficient reason why we know nothing about the oöspores. Until quite recently, this view has been adopted by many botanists.

The migration of a fungus in the track of plants exported for cultivation is not so improbable, as it might at first sight seem. In the case of the Peronospora infestans, we have no accurate record of the migration ; but, within a few years, we have seen a good illustration, in the case of the so-called hollyhock fungus (Puccinia Malvacearum, Mont.), of what might happen in other cases. Some years ago Montagne described a fungus from Chili which was parasitic on certain species of mallows, and which he named Puccinia Malvacearum. At that time, the fungus was entirely unknown both in North America and Europe. A few years ago, a disease began to attack the hollyhocks, members of the mallows family, in the United States. This disease was found to be caused by the growth of Puccinia Malvacearum. A little later the same disease was noticed in England, and later in Central and Southern France, where it attacked the common mallows of the field as well as the cultivated hollyhocks. In 1873 the fungus first appeared in the region of Strasbourg, and in 1874 it had advanced as far as Amsterdam in Holland, and Nuremberg and Erlangen in Germany. This instructive case shows that a parasitic fungus may spread over the world as readily as common weeds have done.

But it may be that the potato-rot fungus is really not a Peronospora at all. It may be a fungus imitating, to a certain extent, the rust in grain, which passes through different stages, in one of which it lives

on the berberry, in another on grain. Perhaps the potato rot, after living for a certain length of time on the potato, and bearing asexual spores, passes in some way to an entirely different plant, and there bears its oöspores. But to what plant does it change? We cannot tell, with the least degree of certainty. There is a suspicion that it may be to clover or grain, wheat or oats, for example, from the general belief that the rot is very likely to appear when potatoes follow either of those crops. Besides, the mycelium of a fungus supposed to have some connection with the potato-rot fungus has been found in clover and straw. Should this really prove to be the case, we shall have gained a valuable piece of information, since in no case should potatoes be planted near or be allowed to alternate with either clover or grain, for fear of propagating the rot. Unfortunately, about this point theories are abundant and facts as yet scanty. There is by no means a unanimity of opinion as to whether potatoes are very likely to rot after clover, wheat, or oats. Of the fungus found on clover and on straw, we know nothing about the fruit of either kind, and, unless there is something more peculiar about the mycelium than we have been given to understand, it would be visionary to trace any particular connection with the potato-rot fungus. Botanists are, however, at work on the subject, and we may expect at any moment valuable discoveries in this direction. Professor De Bary, of Strasbourg, — whose memoir of the Peronosporæ, published in the "Annales des Sciences Naturelles," vol. xx. 1863, is the most exhaustive account of that group yet published, — is still at work, and from him we may receive a solution of the botanical difficulties. In the mean while, the American farmer can contribute something to the general stock of knowledge by noting the apparent effect which a different succession of crops has upon the prevalence of the rot. In the Journal of the Royal Agricultural Society of England, vol. x. part 2, for 1874, are given the results obtained from answers to twenty-five questions, addressed to one hundred potato cultivators in different parts of England. From these answers, it would seem that there is a tendency for the rot to prove particularly bad when potatoes follow clover. Interesting facts on this point might be observed by our own cultivators to supplement those recorded in England, and we would propose the following questions for the consideration of farmers in connection with the rot: —

1. What is the nature of the soil on which you have planted potatoes this year?

2. What crop has preceded the potatoes?

3. What was the preparation of the land for potatoes? What manures have been used?

4. What varieties of potato have you planted, noting whether the varieties were early or late?

5. What was the date of planting?

6. What was the exact date of the appearance of the rot?

7. What varieties seemed to suffer least from the disease?

8. What proportion of the crop was destroyed?

9. On first noticing the rot what was done to save the tubers, and with what result?

10. *Following a clover crop, how are potatoes affected by the rot, particularly badly or not? After potatoes, does clover do well? Have you observed any fungus upon clover?*

11. *Following a wheat, oat, or rye crop, how are potatoes affected by the rot? When wheat, oats, or rye follow potatoes, what is the result?*

Before proceeding to a consideration of the best means of diminishing the rot, let us examine some of the supposed objections to the fungus theory of the disease. It may be premised that such objections are not urged by men of science, and that entomologists as well as botanists acknowledge the fungus origin. We must at the outset distinguish between potatoes affected by the rot, and rotten potatoes. If we take any healthy potato and keep it in a sufficiently wet place, it will become mouldy and, finally, rotten. We shall not find any of the Peronospora infestans on it, however, but ordinary moulds which live upon decaying substances, as Mucor, Penicillium, &c., — moulds which can grow on almost any dead matter, but which do not attack living vegetable tissues. In other words, we have put a healthy potato under such circumstances that it has begun to decay, and then some of the spores of those fungi which live on decaying matter settle upon it, — the air is always full of such spores, — and grow. These moulds do not attack living potato plants, and are not to be dreaded, because we have only to keep the potatoes when harvested in a dry place to avoid all trouble.

In Figs. 6 and 7 are roughly represented two of the common moulds

which attack decaying substances, and are found on potatoes as well as on a great many other substances. Fig. 6 is the fungus known as Mucor stolonifer De Bary (Rhizopus nigricans and Ascophora mucedo of many writers), and is particularly common on bread. Fig. 7 represents the mycelium and asexual spores of Penicillium crustaceum, Fr. (P. glaucum of other writers), which is the common blue mould found on most articles of food.

The potato rot is a totally different thing. Here we have a fungus which attacks the potato plant while it is yet alive, and the crop is destroyed either by a direct invasion of the tubers by the mycelium of the Peronospora, or by the destruction of the tops before the tubers have attained a sufficient size. When the potato plant dies, the

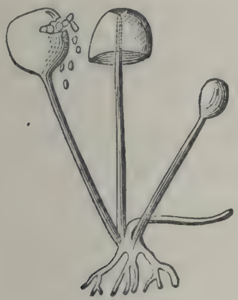


Fig. 6.

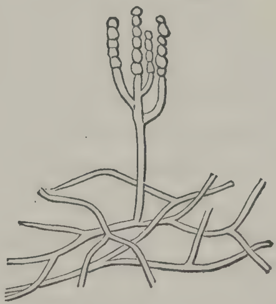


Fig. 7.

Peronospora which has destroyed it, dies with it; but, after it is dead, it may still be attacked by some of the decomposition moulds before mentioned and by insects.

Whatever science may have to say, no season during which the rot has prevailed to any extent ever passes that some cultivator of potatoes does not proclaim to the world that he has discovered that the disease is caused by insects, and offers, as proof, the fact that he has found insects on some rotten potatoes. The mere fact that insects are found on rotten potatoes does not prove any thing whatever as to the cause of the rot. It is quite as logical to infer that the rotten potatoes produced the insects as that the insects produced the rot. To prove the point, one should have found the insects on healthy potatoes, and have noticed that the rot always followed their visits, and did not appear at other times. Those who think there is something in the insect theory, and this number certainly does not include any entomologist, do not

tell us what the insect is, neither do they explain why it is that turnips, carrots, and other roots, are attacked by insects, and yet no disease in the least resembling the potato rot attacks any of these plants.

The theory that the disease arises from an exhausted condition of the potato plant which has been cultivated too long by cuttings is destroyed by the fact that seedlings are affected as well as other plants, and by the fact that the disease prevails amongst the wild species of Peru, where the potato is indigenous. The theory that it is owing to some morbid change in the juices of the potato, and that the Peronospora does not cause the disease, but itself lives upon the morbid products, is overthrown by the following experiment which has been repeated over and over again, and which any one who owns a microscope can easily perform: Slice a potato affected by the rot, and let it stay under a glass until the cut surface is covered by the cotton-wool-like mass of Peronospora. Then slice a sound potato, and place the two halves under different glasses. On one sprinkle some of the Peronospora spores from the first potato, and, in from twenty-four to forty-eight hours, it will become covered with a mass of mycelium and spores, which, under the microscope, will be recognized to be those of Peronospora infestans, and the mycelium will be found running through the tuber in all directions, and the tuber becomes rotten at once. The other half will remain unchanged, except that the cut surface grows a little darker for some days, when a few of the decomposition moulds will be found on it, and it will very gradually decay. Inasmuch then as we always find the Peronospora mycelium in potatoes affected by the rot even before the spots on the leaves appear, and, on the other hand, can produce the disease at will in healthy potatoes by sowing the spores, we need not suppose that any predisposing morbid change in the potato itself precedes the appearance of the Peronospora.

From what we have seen about the cause of the rot and the knowledge which we possess of the habits of the Peronospora, it is evident that there is no such thing as a specific* against it. Whatever completely destroys the fungus will also kill the potato itself, and the farmer who purchases "a sure cure" for the rot, may be perfectly certain that

* By a specific is meant any thing which will not only protect tubers in which there is, as yet, none of the Peronospora mycelium, but which will also prevent the further development of the mycelium in tubers in which it already exists.

he is throwing away his money, as far as accomplishing that purpose, at least, is concerned. The object is to prevent as much harm as possible from being done to the plants in which the mycelium already exists, and to prevent the spread of the disease to healthy plants. If we could control the amount of moisture in the air about the time when the disease is likely to appear, say from the middle of July until the first of September, the mycelium would not increase to any extent to cause practically any harm. That we, unfortunately, cannot do, and all that remains is to drain the land thoroughly, or plant in a dry soil. It is difficult to understand why our farmers persist in planting potatoes in swamps and wet heavy soils, knowing as they do from experience that such plants are always the first to rot. Since the disease does not appear until about the first of August, it follows that the early potatoes should be less likely to rot than late ones. This is found practically to be the case, and early varieties are much to be preferred to late ones. Exactly what variety a farmer should plant is not a question to be decided by a botanist, but it should, at any rate, be a vigorous grower, and ripen as early as possible, the size and marketable qualities being equal. Certain varieties seem to resist the disease better than others, but, as yet, we know of none which may not be attacked, and opinions as to exactly which varieties have the greatest resisting power are so contradictory that it is impossible to decide the matter. The views of persons having potatoes to sell for planting are, naturally, not always unprejudiced, and many farmers have theories on the matter in question which were evolved from their inward consciousness quite as much as deduced from accurate experiments. The Council of the Royal Agricultural Society of England have appointed a Special Committee to examine into the subject of varieties of potatoes which will resist the rot for three years in succession, and several varieties are being tested in twenty different places in the United Kingdom. Two years more must elapse before the results are fully known, and then we may, perhaps, expect more definite information on this important subject than we as yet possess.

The precautions to be taken to prevent the extension of the disease will be more definitely known when the plant in which the oöspores are produced has been discovered. At present, we cannot say with certainty that these are found either in clover, or in wheat, oat, or rye straw, and our knowledge of the subject is still too slight to warrant a

general tirade against the folly of planting potatoes after any of the above-mentioned crops.* There is as yet no sufficient reason for not following them by potatoes if one wishes to, other than that the stubble of some of these crops may make the land more moist than that of others. Potatoes grown upon a soil where grass or clover have previously been ploughed in may suffer from rot, simply because the sods keep the land moist. It is quite probable that the oöspores of Peronospora infestans will be found concealed in some common plant eaten by cattle, and as it is well known that the spores, particularly the oöspores, of many fungi, are so tough that they pass through the alimentary canal of animals without losing the power of germination, it is evident that the chances of avoiding the rot are greater if one makes use of some of the mineral manures in place of animal manure. The fact that certain crops are manured with animal manure, while others are not, may be sufficient to account for the prevalence of the rot when potatoes follow such crops.

It is, of course, of the first importance to avoid planting tubers which are already rotten, but that no sensible farmer would think of doing. How to recognize small amounts of mycelium in nearly sound potatoes does not admit of any practical solution. The botanist who has studied the subject can do it by microscopic examination, but the farmer has neither a microscope nor sufficient knowledge of microscopic manipulation, and, practically, it would not pay to send certain tubers, as samples of a large quantity, to a botanist, to decide on the probable amount of mycelium in the whole. Judging from the results obtained in England, it makes no difference whether the tubers are planted whole or sliced, as far as liability to the disease is concerned. Theoretically, it would appear to be an advantage to plant

* During the last few months, notices have appeared in the Agricultural Reports published at Washington, and in several agricultural journals in different parts of the country, to the effect that, in consequence of the discoveries of Professor De Bary, it is now known that the potato-rot is propagated by means of the oöspores of Peronospora infestans which hibernate in clover and other fodder-plants; and farmers are warned against planting potatoes after these crops. In justice to Professor De Bary, the public should be informed that he has never said any thing which could, in the least, warrant the statements above mentioned. Without saying any thing more about the question whether the rot is really more common after any particular crop, or not, it is unfair to represent Professor De Pary as authority for the sweeping statements of some of our agricultural journals.

deep that the tubers may have less chance for being infected from spores which have fallen on the surface. Practically, this does not work well, but potatoes planted near the surface do best. However, the plan tried by some cultivators in England, with apparently good result, of hoeing the earth up over a good part of the tops as soon as the rot appears, is worthy a trial. Cutting the tops on the appearance of the disease apparently does no good; and, if it appears in a violent form, there is nothing to be done but to dig the remaining sound tubers which, if the variety planted was an early one, are large enough to be of use at the time when the disease is likely to make its appearance.

Although the present article is written with especial reference to the potato rot, a word on the lettuce mould may not be out of place. This disease does considerable harm in the region about Boston where large quantities of early lettuce are raised for the market. Although said by the farmers of Watertown to have troubled them for four or five years, the fungus was first brought to my notice last August, growing on a plant of Lactuca altissima, cultivated in the Botanic Garden at Cambridge. A few weeks later, I received some diseased lettuce leaves from Mr. Locke, of Watertown, who wrote that the fungus caused him a great deal of trouble, particularly on the plants cultivated in hot-beds in the spring. The present month, April, I received more of the leaves from the same gentleman, with the statement that the disease was worse than ever. The appearance of the mycelium, as it breaks through the breathing-pores and bears asexual spores, has been shown in Fig. 3, p. 328. The disease, of course, is most marked on hot-bed plants, since a constantly moist and warm temperature is kept up, and the pecuniary loss to the gardener is greatest as the early lettuce brings a higher price than that which grows later in the season in the open air, and which is less likely to be affected by the mould. The belief of some farmers that the disease is caused by watering with well-water, is, of course, entirely without foundation. The disease may be diminished by not watering the hot-beds too much, and by opening the frames frequently to admit the outside air. It is a good plan, once in a while, say once a fortnight if the weather permits, to keep the frame open towards night, so that the plants may be exposed to a temperature near the freezing point. Freezing, of course, injures or kills the plant, but a temperature as near freezing as possible without serious injury to the

lettuce will put back the fungus so far that it does not recover for some time. If the disease has prevailed one season, the hot-beds of the next season should be made in some other locality, and if possible only seed from sound plants should be sown. As soon as the leaves mould they should be removed, and care should be taken not to throw them where they will be likely to get into heaps of manure which are to be used the next season. The common weed known as groundsel (Senecio vulgaris) should be removed with great care. It is found in hot-beds and all cultivated fields, and does more to spread the lettuce mould than the decayed lettuce leaves themselves, since in the groundsel, the oöspores of Peronospora gangliformis are more abundant than in any other plant.

No. 16. — *A Report on some Analyses of Salt-marsh Hay and of Bog Hay*. By F. H. Storer, Professor of Agricultural Chemistry.

Ever since the settlement of New England, hay prepared from the natural grasses of the salt marshes on the seaboard and of the fresh-water marshes or so-called meadows,* which abound in the interior, has held a conspicuous place among the agricultural products of the country. Though far less important at the present time than it was formerly, the use of such hay is still common. It has had an unmistakable influence upon the farming practices that prevail among us; and the discovery of any new facts that concern it will be interesting, not merely from the novelty of these facts, but from their bearing upon the history and the development of agriculture in this region.

The opinions of our farmers as to the worth of these "salt" and "fresh" hays, as compared with that of "English" † or upland hay, upon the one hand, and that of straw on the other, have varied widely at different times and in different places, as will be shown directly. The merit of salt hay has often been extolled, and the general worthlessness of bog hay has been insisted upon even more frequently. Of late years both sorts seem to be less generally esteemed than they were formerly, and there is manifestly a strong tendency on the part of agricultural writers to condemn the hay both of salt and of fresh marshes as a product that has usually very little real value as forage. But it is none the less true that such hay continues to be used for foddering animals over a wide extent of country, that the use of these natural hays is still a conspicuous and an interesting feature of Amer-

* The word "meadow," commonly applied in New England to low, boggy land, overgrown with sedges and other forms of coarse natural herbage, is an English provincialism, apparently peculiar to that part of the country whence many of the colonists came. The prevalence of the term in Massachusetts is manifestly due to the same causes that determined the names of several of our oldest counties and towns. See Marshall, W., "The Rural Economy of Norfolk," London, 1795, **1.** pp. 312-318, and **2.** 383.

† That is to say, the hay from fields that have been regularly cultivated, and seeded down according to American custom with timothy, or timothy and red-top, or with a mixture of these grasses and clover.

ican agriculture, and that there is little likelihood of a custom so firmly rooted and so widely spread being soon discarded.

In the hope of adding something to our knowledge of the subject, I have had several samples of salt- and of fresh- hay subjected to analysis, according to the method commonly employed by agricultural chemists, as explained on page 26. The results of this work will appear from the following record. All the analyses were made in the winter of 1874–75, with the exception of that of white-weed hay, and one or two determinations of moisture and ash in the fresh grasses. The estimations of water were made at 110°, unless otherwise expressly stated.

A. Hays from Salt Marshes.

1. Salt hay obtained in 1872 (crop of that year) from J. R. Brewer, Esq., of Hingham, Mass. The sample taken for analysis consisted of a mixture of spike-grass (*Brizopyrum spicatum*), rush salt-grass (*Spartina juncea*), and some sea spear-grass (*Glyceria maritima* *). As originally received, the sample of hay contained some stalks of the coarse "salt-marsh grass" (*Spartina stricta*), and of "black grass" (*Juncus bulbosus*); but most of them were picked out and thrown away in preparing the hay for analysis. All the samples of salt hay obtained at Hingham grew upon a rather narrow strip of marsh lying between the upland and a tidal creek of brackish water. The hay had been kept in a dry loft at the Bussey Institution since 1872.

2. Salt hay obtained in 1874 (crop of that year) from J. R. Brewer, Esq., Hingham, Mass. The sample analyzed contained much spike-grass, some black grass, and a few stalks of upland grasses (*Calamagrostis ?* or *Agrostis*). No sea spear-grass was noticed.

3. Another sample obtained in 1874 from J. R. Brewer, Esq., of Hingham. The portion analyzed was mainly spike-grass mixed with sea spear-grass, besides some stalks of upland grass (*Poa*) and a little black grass. There was less black grass in this sample than in No. 2.

* Gasparin (in his "Cours d'Agriculture, 3me dit.," vol. 4.) reports that the hay of this excellent grass contains 1.88% of nitrogen, *i.e.*, 11.73% of albuminoids. He reports also that the grass loses 58% of its weight when made into hay. Sinclair (quoted in H. Davy's "Elements of Agricultural Chemistry," Appendix) found that 100 lbs. of this grass ("*Poa maritima*") cut at the time of flowering gave 40 lbs. of hay.

4. Salt hay from Mr. B. Dexter's marsh, near Weweantitt River, Marion, Mass., crop of 1874. The sample was mainly rush salt grass, with here and there a stalk of spike-grass. There was some black grass also, which was removed as completely as possible before the analysis.

5. Salt hay obtained from Joseph Church, Esq., Rochester, Mass., crop of 1874. The grass grew on Angelico Point, Mattapoisett, Mass. The hay was a particularly clean, bright sample, consisting almost entirely of rush salt grass (*Spartina juncea*).

The following table shows the results obtained on analyzing the foregoing five samples of hays from the

Short Salt-grasses:	I.	II.	III.	IV.	V.	Mean of the 5 Analyses.
Water	7.93	8.91	7.84	8.70	8.61	8.40
Ash (free from C and CO_2)	6.29	7.79	7.10	7.51	5.97	6.93
Albuminoids	7.09	7.53	7.79	4.88*	4.38*	6.33
Carbohydrates (including fat) by difference . . .	47.29	42.87	43.43	50.20	43.13	45.38
Cellulose (free from ash) .	31.40	32.90	33.84	28.71†	37.91	32.96
	100.00	100.00	100.00	100.00	100.00	100.00
Dry organic matter . .	85.78	83.30	85.06	83.79	85.42	84.67
Fat, &c. (*i. e.*, ether extract)	2.90	3.14	2.77	1.68	1.83	2.46
Nitrogen	*a.* 1.12	1.21	1.25	0.75	0.68	0.98
	b. 1.15	1.20	1.25	0.81	0.71	
Crude ash	6.29	7.85 7.89	7.16	7.51	5.97	7.11

6. Coarse salt hay obtained in 1872 (crop of that year) from J. R. Brewer, Esq., Hingham, Mass. The sample consisted entirely of salt-marsh grass (*Spartina stricta*, variety *alterniflora*), commonly called "sedge," in this vicinity. There were neither seeds nor flowers upon this sample of hay.

7. Similar to No. 6, and from the same locality, but obtained in 1874, from crop of that year.

8. A very good sample of *Spartina stricta* from Marion, Mass., near mouth of Weweantitt River, crop of 1874. A considerable amount of sand could be seen adhering to this sample.

The results obtained on analyzing these coarse salt hays will be seen in the following table.

* The exceptional character of Nos. 4 and 5 may be seen on the general table, page 352.

† Mean of two determinations, viz., 28.92% and 28.50%.

Coarse Salt-hays:	VI.	VII.	VIII.	Mean of the 3 Analyses.
Water	11.70	17.47	18.61	15.93
Ash (free from C and CO_2) .	9.84	9.56	11.81	10.41
Albuminoids	4.33	5.55	5.38	5.09
Carbohydrates (including fat)	43.59	37.41	36.56	39.18
Cellulose (free from ash) . .	30.54*	30.01	27.64	29.39
	100.00	100.00	100.00	100.00
Dry organic matter	78.46	72.97	69.58	73.67
Fat, &c. (ether extract) . .	2.29	2.26	2.49	2.35
Nitrogen	0.69	{ 0.88 / 0.89 }	{ 0.84 / 0.87 }	0.83
Crude ash	9.84	9.56	11.81	10.41

9. Black grass (*Juncus bulbosus*, variety *Gerardi*, or *Bothnicus*) from J. R. Brewer, Esq., Hingham. The specimen analyzed was obtained by picking out spears of black grass from the original sample of salt hay from which sample No. 2 (see above, page 340) had been taken. Since only those portions of the black grass to which seed-vessels were attached were easily recognizable, and since many of the stalks were broken, the sample analyzed consisted for the most part of the upper portions of stalks, together with very many seed-vessels, though no seeds were contained in them.

10. Black grass from Marion, Mass., near mouth of Weweantitt River, crop of 1874. An excellent sample, "not wet in curing." There were many seeds upon the stalks in the sample taken for analysis.

Black Grass Hay:	IX.	X.	Mean of the Two Analyses.
Water	7.17	10.25	8.71
Ash (free from C and CO_2) .	4.90	5.48	5.19
Albuminoids	7.39	6.18	6.79
Carbohydrates (including fat)	44.64	47.66	46.15
Cellulose (free from ash) . .	35.90	30.43	33.16
	100.00	100.00	100.00
Dry organic matter	87.93	84.27	86.10
Fat, &c. (ether extract) . .	2.09	2.51	2.30
Nitrogen	1.18	{ 0.98 / 0.99 }	1.05
Crude ash	4.90†	5.65 — 5.87†	5.47

* Mean of two determinations, viz., 30.14% and 30.93%.

† Sprengel (Erdmann's "Journal tech. und œk. Chemie," 1829, **5.** pp. 61, 295, and 1831, **10.** 48) found much more ash (8.1% of the dried hay) in a sample of the variety of black grass from the sea-shore, "*J. Bothnicus*," which is the more common form in this country, than in *J. bulbosus*, from an apparently

11. Seeds of black grass from Marion, Mass. A considerable quantity of the seeds of black grass were collected early in March, 1875, from the bottom of the mow from which the sample of hay No. 10 had previously been taken. The sample was carefully freed from admixed sand and from the seeds of other plants by repeatedly sifting and blowing upon it, so that a good sample was obtained for the analysis, which resulted as follows: —

Analysis of Black Grass Seeds.

Water (in the powdered seeds)	7.98
Ash (free from C and CO_2)	2.65
Albuminoids	15.89
Carbohydrates (including fat)	50.56
Cellulose (free from ash)	22.92
	100.00
Dry organic matter	89.37
Fat *	3.33
Nitrogen	2.52 — 2.56
Crude ash	2.65

It will be observed that the results of the foregoing analyses of salt-marsh hays fall naturally into two or three distinct groups or classes. Black-grass hay, and the hay from the mixture of grasses that grow upon brackish marshes, are manifestly of decidedly better character than the hay of the rush salt grass (*Spartina juncea*), or "red salt grass," as it is sometimes called. The tall, coarse salt-marsh grass (*Spartina stricta*), or so-called "sedge," on the other hand, exhibits certain peculiarities of its own, among which the comparatively high proportion of water and of ash contained in it are conspicuous.

It is hardly to be presumed that either of the samples of hay from the brackish marsh grasses were of the very best quality. In most instances the hay had probably been cured too late in the season. There were many seeds, it is true, in the sample of black-grass hay,

brackish, inland meadow, which gave only 3.9% of the dried hay. He found also in one sample of green black grass 62% of water, and in another 60%. Mr. John Welles, of Dorchester ("Massachusetts Agricultural Repository," 1825, 8. pp. 74, 76), found that 100 lbs. of black grass cut July 18, 1823, gave 38 lbs. of hay.

* The ethereal extract in this instance, unlike the extracts from the hays, which were largely contaminated with the coloring matter of chlorophyl, was well-nigh pure fat, of faint, greenish color, as good as that obtainable from bran.

No. 10; but the hay was over-ripe, nevertheless, since many of its seeds had evidently been shed. No one of the analyses indicates hay of so good quality as a sample of salt-meadow hay from the German Island Poel in the Baltic Sea, that was examined by G. Lehmann,* some ten or twelve years ago, and which contained —

Water	15.67
Ash (free from sand)	6.49
Albuminoids	11.87
Carbohydrates (including 3.2% of fat, *i.e.*, ether extract)	38.45
Cellulose	27.52
	100.00

It should be observed in this connection that my purpose was to find out the composition of hays such as are actually used by the generality of farmers in New England. It was no part of my plan to collect at this time the best possible samples.

B. Fresh-meadow or Bog Hays.

1. A sample of the sedge *Carex stricta*, growing in tufts or hassocks on a moist meadow upon the Bussey Farm, was gathered by hand June 11, 1873, and carefully dried in a loft, where it was placed immediately after cutting. When dry, the hay was packed in a paper bag, and kept in a dry place until analyzed, in December, 1874. The sedge was "going to seed" when cut, and a large number of its seeds fell from the stalks during the process of drying. (For a partial analysis of these seeds, see page 348.) But many of them still remained adhering to the dry stalks, and were included in the sample taken for analysis.

2. Another sample of *Carex stricta*, gathered by hand June 16, 1873, from a wet meadow a mile or more to the eastward of the preceding locality. This sample was collected at 7½ A.M., while drops of dew were still clinging to a few of its leaves. It was taken immedi-

* "Die landwirthschaftlichen Versuchs-stationen," 1864, 6. 483. About 50% of this hay was black grass cut when in blossom; from 30 to 40% was *Agrostis alba* that had passed the time of flowering; and the remaining 10 to 20% consisted of a mixture of *Ammophila baltica*, the flower-stalks of *Armeria vulgaris*, and plants (bearing ripe fruit) of *Glaux maritima*, *Triglochin maritimum*, and *Spergula arvensis*, together with fragments of other kinds of grasses and herbs that could not be determined. Lehmann mentions particularly that many of the components of this mixture of dried grasses were "young and tender."

ately to the laboratory, and the amount of moisture contained in it was determined without loss of time. Dried at 100° C., the green grass lost 65.97% of its weight.* This grass contained 1.35% of ash.

3. Bog hay (*Carex stricta?*) from Mr. J. Hathaway, Rochester, Mass., mown August, 1874. No seeds nor flowers could be detected in the sample. Many of the stalks or leaves were dead, or nearly so.

4. Bog hay (*Carex stricta?*) from Mr. Joseph Church, Rochester, Mass., crop of 1874. Some of the stalks or leaves in the original sample were dead; but as many as possible of these dead stalks were thrown out from the portion taken for analysis.

5. A sample of dead and weather-beaten sedge (*Carex stricta?*) gathered by hand, December 26, 1874, in a meadow upon the farm of Mr. D. Lewis, Rochester, Mass.

The result of these analyses will appear from the following tables: —

Bog hays (gathered by hand):	I.	II.	Mean of the Two Samples.
Water	7.46†	7.33	7.40
Ash (free from C and CO_2)	6.52	6.17	6.34
Albuminoids	10.41	9.38	9.90
Carbohydrates (including fat)	42.01	43 21	42.61
Cellulose (free from ash) .	33.60	33.91	33.75
	100.00	100.00	100.00
Dry organic matter . . .	86.02	86 50	86.26
Fat, &c. (ether extract) .	2.21	2.13	2.17
Nitrogen	1.66 — 1.67	1.49 — 1.51	1.58
Crude ash	6.58	6.32	6.45

* Mr. John Welles, of Dorchester, reported in the "Massachusetts Agricultural Repository" for the year 1823, **7.** 311, and for 1825, **8.** pp. 74, 76, that he had found in 1822 that 100 lbs. of green "fresh-meadow grass" gave 38 lbs. of hay, and in 1823 that 100 lbs. of fresh meadow-grass, cut July 23, gave 44 lbs. of hay.

In one of the upland sedges (*Carex muricata*), gathered when in blossom, Sprengel (Erdmann's "Journal tech. und œk. Chemie," 1830, **9.** 12) found 60% of water, and 4.07% of ash (=10.17% of the anhydrous hay).

Witting ("Journal praktische Chemie, 1856, **69.** 153) found in fresh plants of *Carex remota* 52.75% of water (on drying at 100°) and 2.07% of ash; in *Carex acuta*, 69.60% of water and 1.12% of ash; and in *Juncus communis*, 62.00% of water and 1.42% of ash. Detailed analyses of the ashes of these plants have been given by Witting in the cited memoir.

† An estimation of moisture made June 24, 1873, *i. e.*, ten days after the sedge was gathered, gave 7.96% (dried at 100° C.). A determination of crude ash made at the same time indicated 6.66%, calculated on the air-dried hay.

Bog hays (from barns):	III.	IV.	Mean of the Two Samples.
Water	7.96	8.38	8.17
Ash (free from C and CO_2)	5.65	5.43	5.54
Albuminoids	6.31	7.44	6.88
Carbohydrates (including fat)	46.53	45.45	45.99
Cellulose (free from ash)	33.55	33.30	33.42
	100.00	100.00	100.00
Dry organic matter	86.39	86.19	86.29
Fat, &c. (ether extract)	3.00	1.92	2.46
Nitrogen	0.99 — 1.02	1.17 — 1.20	1.09
Crude ash	5.86 — 5.88	5.54 — 5.57	5.71

	Dead bog hay. V.	Sample of bog hay analyzed at New Haven.†
Water	9.32	8.00
Ash (free from C and CO_2)	4.42	3.54
Albuminoids	4.63	8.37
Carbohydrates (including fat)	41.64	46.16
Cellulose (free from ash)	39.99	33.93
	100.00	100.00
Dry organic matter	86.26	88.46
Fat, &c. (ether extract)	0.74	3.32
Nitrogen	0.73 — 0.75	
Crude ash	4.42 *	

* The clean white ash totally free from C and CO_2, left by the dead hay, was in marked contrast with the gray ashes from the other samples.

† See Professor Johnson's statement in "Sixth Report of the Sec. Connecticut Board of Agriculture," 1872, p. 422. The amount of water actually found in this sample is not given. But in order that the results of the analysis may be readily compared with the others, I have recalculated Johnson's figures on the assumption that his hay contained 8% of water.

It is noteworthy that the proportion of moisture contained in most of the hays and plants described in this article is decidedly smaller than the amounts that have ordinarily been reported by European analysts. (See, for example, the tables in Johnson's "How Crops Grow," page 385.) It would perhaps be premature to assert that this difference is due solely to the extreme dryness of the air in New England during winter, for it may be that the plants analyzed above were exceptionally dry, and that (as seems probable) the mechanical texture of the bog hays is not favorable for the retention of moisture. There can be little doubt, however, in view of the dryness of our climate, that hay is in general actually drier here in New England during the winter, and probably at all times, than it is in Germany and in England. I hope to study this point

It will be noticed that samples Nos. 1 and 2 of the bog hay that were collected by hand in the month of June were of distinctly better quality than the samples Nos. 3 and 4, taken from farm barns, which had been mown later in the season. Nos. 3 and 4 were of course much better than the specimen taken in the month of December, from a tuft in the field, where it had been exposed to the frost and storms of autumn. The sample of sedge hay analyzed at New Haven was probably mown earlier than the samples 3 and 4 of the above list. For the comparison of all these samples, see the general table beyond. It is to be noted that not a single one of the five specimens of hay from sedge here examined was obtained under the best possible conditions. Even the grass from which the best hay of all (No. 1) was prepared, was over-ripe when cut, as has been already stated on page 344.

It is to be remembered that most sedges blossom very early,* even earlier than the greater part of the true grasses. But, in order to obtain good nutritious hay from any grass or grain, the crop should not be mown later than the time of flowering. Hence the common practice of curing sedge hay in July or August is plainly improper, in so far as concerns the chemistry of the question. It is obvious that a decided improvement in the character of bog hay might be brought about by the exercise of a little discretion, if the condition of the low land upon which the sedges grow, and the press of other farm work, would but permit the mower to cut them at an appropriate season. 344.

experimentally at some future time, with the view of determining how large a correction should be applied by our farmers, on account of this difference of moisture, to tables of the fodder value of forage that have been compiled in the interest of European farmers, on the basis of the 14 or 15% of water which is there found in hay. It may perhaps be found best, eventually, to give in the tables of fodder value, only the composition of the anhydrous hays, with the understanding that in respect to the item " water " a special correction shall be applied for each particular country or climate, according to the mean monthly or yearly humidity of the air in that locality.

Since the foregoing paragraph was written, an estimation of the amount of moisture contained in a fair sample of timothy hay has been made in the Bussey laboratory, with the result that the hay lost only 7.80 % of its weight on being dried at 110° C. This sample of timothy was taken from a barn at Rochester, Mass., in March, 1875, and was subsequently exposed during a couple of days before weighing, in a cold loft at the Bussey Institution, at a time that was by no means particularly dry.

* The sedges are " perennial herbs, chiefly flowering in April or May, frequently growing in wet places, often in dense tufts." Gray's " Botany of the Northern United States," article *Carex*.

A partial analysis of the seeds of *Carex stricta* that fell from sample No. 1 (page 344) during the process of drying, gave the following results. 100 parts of the air-dried seeds contained —

Water (expelled on heating to 110° C.)	7.42
Nitrogen	2.22 — 2.25
Albuminoids	13.97

C. Analyses of Hay from the Common Rush, the Flowering Fern, Buttercups, White Weed, and the Beach Pea.

In connection with the foregoing experiments on grasses and sedges, analyses have been made of hays from several other plants, which have a certain interest and value as forage, of the same general kind as that which attaches to the bog and marsh hays, properly so called.

6. A sample of hay of the Common or Soft Rush (*Juncus effusus*) from Rochester, Mass, crop of 1874, probably mown in August. The sample was taken from a bunch of carex, with which it had been cut.

7. Hay of the great Flowering Fern (*Osmunda regalis*) from Mr. Obed Clifton, Marion, Mass., crop of 1874. Grown on a wet meadow. The plant is commonly called "Mount Royal" in that part of the State where the sample was obtained.

Some farmers esteem the flowering fern as a plant of considerable value for foddering purposes. Compare, for example, the following extract from the Report of Committee on Sheep in the "Transactions of the Essex County Agricultural Society" for 1860, page 56: —

"We think that we are favorably situated in this county for raising lambs for early market. Sheep are fond of salt hay and the coarse grasses that grow upon our fresh meadows, particularly the *Osmunda spectabilis*, or buckhorn. By giving them a small quantity of beans or corn daily, they can be wintered well; and, if the lambs are sold early, they will recruit before winter, even if they are required to feed our pastures closely."

8. Hay of Buttercups (*Ranunculus acris*), from plants that were gathered by hand June 16, 1873, upon a rather shady hillside in Jamaica Plain. The soil upon which the plants grew was poor and cold. The plants were passing out of flower when gathered, but no seeds were ready to drop; they were dried in a loft, and kept in a paper bag until analyzed in the winter of 1874–75. As is well known,

cattle avoid the green plant because of its acrid juices; but the pungency is lost during the process of drying, when the plant is cut for hay.

9. Hay of White Weed, or Ox-eye Daisy (*Leucanthemum vulgare*). The plants were gathered by hand June 30, 1872, on a field adjoining the Plain-field of the Bussey Institution; they were in full flower, and the bottoms of the stalks were beginning to turn stiff and dry. The hay would doubtless have been of better quality if the plants had been gathered earlier. The plants were dried within doors, and the analyses made in the month of July following. The water was estimated at that time at 110°. A subsequent determination of the amount of water, made at 100° in December, gave only 7.69%, instead of the 10.87% that had been found in July, on drying at a slightly higher temperature. The results of this analysis have been reported already on page 36.

10. Hay of Beach-pea vines (*Lathyrus maritimus*), gathered upon Nantasket Beach, Cohasset, Mass., June 24, 1873. The vines were dried within doors, and kept in a paper bag in a dry loft until analyzed, like the other samples, in the winter of 1874–75.

The beach-pea is a plant of considerable scientific interest, because of its vigorous growth, often in the merest sand or shingle, under conditions which would seem to be most unfavorable for the development of such succulent and nutritious herbage. The results of the analyses given below show that the plant is really as rich as it appears to be in those ingredients that compose the better kinds of forage. The beach-pea has very long and vigorous roots, that extend to great distances in the loose materials upon which it commonly grows. Hence the food of the plant is doubtless collected from far and wide. It would be of interest to determine by experiment whether this plant is susceptible of cultivation, or of being made to grow thickly upon any considerable surface of sand, by the application of fertilizers. According to Mr. J. L. Russell, as cited in Colman's "Fourth Report on the Agriculture of Massachusetts," page 524, the beach-pea vines are eaten by horses. There are many localities on the seaboard of New England where the plant would seem to be worthy of more attention on the part of farmers than appears to have been given to it hitherto.

11. Hay of Beach-pea vines gathered at Bar Harbor, Mount Desert, Maine, July 16, 1873. The plants were growing at a point where the shingle of the beach joins the earth of the upland. They seemed to be better situated as regards their supply of food than the plants of Nos. 10 and 12. This sample was dried in the open air, and afterwards kept in a loft, like No. 10.

12. Hay of Beach-pea vines from a low sand dune on north shore of Nonamesett Island, Buzzard's Bay, Mass., gathered 28 August, 1873. This sample was dried in the open air and afterward stored, like the others. A tolerably large proportion of the sample consisted of rather young shoots, but there were many older stalks also.

The composition of these seven specimens will appear from the table on page 351 : —

For the sake of ready comparison, the average composition of all the hays above described (as determined by the foregoing analyses) is given in the general table on page 352.

A table such as this, based solely upon analyses of the hays, though valuable in enabling us to contrast the composition of the several kinds enumerated with that of the ordinary hays and straws, previously examined by chemists, cannot of course settle the question as to the fodder value of the salt and fresh hays with that certainty that may be gained by a combination of the analytical method with practical experiments in foddering animals. By feeding several animals upon hay (and other matters) whose composition has been precisely determined by analysis, and estimating from day to day, during a considerable interval of time, the amounts of each ingredient of the fodder that are discarded undigested, that is to say unused, in the excrements of the animals, and observing how much the animals lose or gain in flesh meanwhile, the real value of any kind of fodder, and of its several components, may be determined with a considerable degree of accuracy. But such trials necessarily consume a great deal of time and labor; and, until they shall have been made, the most trustworthy opinions as to the worth of salt and fresh hay that can be formed will have to be based upon the evidence now accessible; namely, that furnished by analysis on the one hand, and by the records of farming experience upon the other. Before proceeding to discuss the testimony last

	VI. Hay of Common Rush.	VII. Hay of Flowering Fern.	VIII. Hay of Buttercups.	IX. Hay of White Weed.	X. Beach-pea Vines from Cohasset.	XI. Beach-pea Vines from Mt. Desert.	XII. Beach-pea Vines from Buzzard's Bay
Water	6.88	8.23	8.24	10.87	7.88	7.18	7.79
Ash (free from C and CO_2)	2.63 ?	6.73	5.21	6.44	6.99	6.54	8.60
Albuminoids	6.75	7.38	10.66	7.00	23.25	14.66	18.19
Carbohydrates (including fat)	42.26	52.07	45.19	44.69	32.53	41.60	38.43
Cellulose (free from ash)	41.48	25.59	30.70*	31.00	29.35	30 02	26.99
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry organic matter	90.49	85.04	86.55	82.69	85.13	86.28	83.61
Fat	. . . .	2.97	3.64	2.42	4.95	4.96	3.04
Nitrogen	1.08	1.16 — 1.20	1.70 — 1.71	1.12	3.67 — 3.70 — 3.79	2.27 — 2.42	2.89 — 2.93
Crude ash	2.63	6.88	5.92	7.61	8.01	7.83	9.50

* Mean of two determinations 29.40 and 32.00.

Name of the Hay.	Water.	Ash (free from C and CO_2).	Albuminoids.	Carbohydrates, including fat.	Cellulose.	Dry Organic Matter.	Fat, *i.e.*, Matters soluble in Ether.
Better kinds of Salt Hay from brackish marshes (mean of three samples).	8.23	7.06	7.47	44.53	32.71	84.71	2.94
Black Grass Hay (mean of two samples)	8.71	5.19	6.79	46 15	33.16	86.10	2.30
Rush Salt Grass (mean of two samples)	8.65	6.74	4.63	46.67	33.31	84.60	1.76
The coarse Salt-Marsh Grass (mean of three samples).	15.93	10.41	5.09	39.18	29.39	73.67	2.35
The German sample of Hay from a brackish meadow (see p 344)	15.67	6.49	11.87	38.45	27.52	77.86	3.20
Sea Spear Grass (*Glyceria maritima*) examined by Gasparin (see p. 340) . .			11.73				
Bog Hay, carefully cut and cured in June (mean of two samples).	7.40	6.34	9.90	42.61	33.75	86.26	2.17
Bog Hay, taken from barns (mean of two samples) .	8.17	5.54	6.88	45.99	33 42	86.29	2.46
Bog Hay, Prof. Johnson's sample (see p. 346) . . .	8 00	3.54	8.37	46.16	33.93	88.46	3.32
Dead Bog Hay collected in a field in December . . .	9.32	4.42	4.63	41.64	39.99	86.26	0.74
Common Rush (taken from a barn)	6.88	2.63	6.75	42.26	41.48	90.49	
Flowering Fern (taken from a barn)	8.23	6.73	7.38	52.07	25.59	85.04	2.97
Buttercups.	8.24	5.21	10.66	45.19	30.70	86.55	3.64
White Weed,* cut in flower (see p. 36)	10.87	6.44	7.00	44.69	31.00	82.69	2.42
Beach-pea Vines (mean of the three samples) . . .	7.62	7.38	18.70	37.53	28.79	85.01	4.32

* The question whether dried white-weed has any fodder value has been debated for many years in this vicinity. For a strong statement in its favor, made by a Maine farmer, see Fessenden's "New England Farmer," 1826, **4.** 37.

There can be no question that hay fields infested with white-weed should be mown very early, before any of seeds of this plant have matured, for the

named, it will be well to interpolate a table of the average composition of hay and straw, as determined by European chemists.*

Name of the Plant.	Water.	Ash.	Albuminoids.	Carbohydrates, including Fat.	Cellulose.	Dry Organic Matter.	Fat.
Meadow Hay	14.59	6.54	10.11	43.24	25.52	78.87	2.34
Rowen	13.92	8.58	12.62	42.85	22.03	77.50	3.64
Wheat Straw	13.55	3.94	3.03	41.00	37.48	82.51	1.10
Rye Straw	13.00	3.97	3.61	34.77	44.65	83.03	1.35
Barley Straw	13.31	7.15	3.57	33.97	42.00	79.54	1.90
Oat Straw	13.63	5.26	4.55	38.59	37.97	81.11	1.64
Pea Straw	14.28	4.13	7.56	31.56	42.47	81.59	2.17
Pea Hay (cut in blossom)	16.70	7.00	14.30	36.80	25.20	76.30	2.60
Hay of the Fodder-Vetch, or Tare	14.90	9.00	17.60†	32.05	26.45	76.10	2.30

The relatively large proportion of water reported in analyses of European hays and straws of course makes it somewhat less easy than could be wished to compare the figures in the above table with those of the table previously given on page 352. It will nevertheless be seen at a glance, on contrasting the two tables, that the proportion of albuminoids in meadow hay (*i.e.*, "English hay") is decidedly larger than it is in the salt hays and the bog hays, and that the proportion of cellulose is decidedly smaller. With regard to the straws, on the contrary, the reverse of this is true. The proportion of carbohydrates also is in almost every instance much smaller in the straws than in the bog and salt hays. It is plain, in short, that the chemical composition of the bog and salt-marsh hays is much more nearly related to that of true meadow hay than it is to the composition of straw.

double purpose of saving the fodder which the young stalks afford and of preventing the weed from spreading. A somewhat similar remark would apply of course to fields that are overrun with buttercups.

* The items in this table are copied from the elaborate work of Dietrich and Kœnig, entitled "Zusammensetzung und Verdaulichkeit der Futterstoffe," Berlin (Springer), 1874.

† The percentage of albuminoids ranged from 14.2 to 20.4 in the samples from which this average was taken. If the average percentage of water in the samples had been 7.8, instead of 14.9 as above, the percentage of albuminoids would have been from 15½ to 22, very much like the beach-pea (see page 351).

This general fact consists perfectly with the actual farming practice of New England. Speaking comparatively, very little straw has ever been used as fodder in this region, while salt hay and bog hay have always been used largely, not to say universally, as regards the latter. It is plain, therefore, in spite of what has been sometimes over hastily asserted, that bog hay is esteemed by our farmers to be decidedly better fodder than straw. A like remark will apply to salt hay also, though, from the necessarily local significance of the latter, it can never have been so generally put in contrast with straw.

The history of the use of salt hay in New England is a peculiar one. As has been said already, such hay was formerly held in high estimation, but it has latterly fallen into comparative disrepute. As recently as 1830, a committee of the Agricultural Society of the County of Essex, which is said to contain about five-elevenths of all the salt marsh in Massachusetts, reported as follows: —

"Salt hay, when well cured, is a very valuable feed for neat cattle and horses, and may be fairly considered as equivalent in value to more than one-half of the same amount of English hay. . . . A mixture of this feed with English hay is conducive to the health of the animals fed upon it, and is proved to be as agreeable as it is nutritious by the avidity with which they seize upon it." *

Mr. Colman,† in reporting upon the same county, speaks as follows: "The average product of well-managed salt marshes is from three-quarters of a ton to a ton and a quarter. The hay is valued at half the price of English hay. In Salem and Boston markets, where it is purchased for a change of diet or to be mixed with English, it usually brings two-thirds of the price of English. The farmers in the interior of the county, even at a distance of fifteen miles or more from the sea-shore, are glad to own or hire a piece of salt marsh, considering a portion of this fodder of great service to the health of their stock. A shrewd farmer in Lynn considers salt hay as worth five dollars a ton, merely to spread upon his grass land for manure. His judgment is to be relied upon. It is stated likewise that those farmers who carry it into the interior in a green state, and cure it in their fields, find this process almost equal to a top dressing of manure. This comes undoubtedly from the salts which it deposits. The quantity of salt hay which is cut enables the farmers to sell much of their English hay, without injury to their farms. . . . Considerable quantities of fresh-meadow or swale hay are cut; but it is composed of aquatic plants which contain little nourish-

* "Transactions of the Essex Agricultural Society," 1831, p. 44.

† "First Report on the Agriculture of Massachusetts," by Henry Colman, Boston 1838, p. 19.

ment, and is of comparatively little value. The manure of cattle fed upon it or littered with it is of inferior quality."

A few years later a different story begins to be told. Thus Mr. Newhall, in addressing the Essex County Society in 1849,* says: "Our salt marshes, which have been a reliable source for stock fodder, have within a few years been thought less of than formerly. The cattle fed upon the hay grown from them have been represented by a gentleman who stands high in our society as the successors of Pharaoh's lean kine."

Upon the Connecticut shore the same opinion prevails. In 1869, Mr. Albert Day, in his report as delegate to New London County,† says: "There are thousands of acres of salt marsh all along the southern shores of the county, yielding a poor grass that serves for bedding, and just pays for cutting." And in 1873, the Rev. Mr. Clift, in his lecture on Marine Manures,‡ remarks: "From the first settlement of the country, it has been a favorite investment with the farmers living back six or eight miles from the shore, to have a piece of salt marsh, even if they could not get more than an acre, for the purpose of cutting the grass and carrying it to their farms. It has been thought until quite recently to have considerable value as fodder, but they are losing their faith in it as an article of food ; their confidence in it as manure, however, abides. It is found that where a salt-hay stack is foddered out, it leaves its mark. If the land is turned up and planted with corn, they get very excellent corn. The hay is used a good deal for bedding, and is thrown out with the rest of the manure into the compost heap, and it is also used for covering plants about the garden."

One reason for this change of opinion may fairly be attributed to the improved character of the upland hay in New England in late years. No doubt but that salt hay was better than it is now, as compared with upland hay, in the days when the almost universal custom among our farmers was to harvest their hay comparatively late in the season, under the belief that there would be great loss from "shrinkage" if the grass were mown before it was "ripe." There can be little question but that the quality of the upland hay harvested in New England has been, on the whole, greatly improved since our farmers have learned that grass should be cut before its nutritive matters have been converted into seeds, and the stalks left mere straw. When put in comparison with over-ripe upland hay, the better kinds of salt hay were doubtless really excellent.

* "Transactions Essex Agricultural Society, 1849, pp. 7, 8.

† In Report of the Sec. Connecticut Board of Agriculture, 1869, p. 394.

‡ *Ibid*, 1873, pp. 203, 204.

There are, manifestly, several other reasons why salt hay should be less highly esteemed nowadays than it was when the condition of the country was different. At the time when our farmers were in the habit of wintering as many cattle as possible, in medium or low condition, for the sake of utilizing the summer pasturage, the accumulation of large quantities of bulky fodder, at the least possible cost, was an important point in good husbandry. So, too, the fact that salt hay is greatly relished by cattle, when given to them either as a condiment or for the sake of a change of diet, was a point of much greater significance formerly than it is now, when a great variety of foddering materials fit to serve these purposes can be bought in our markets. The difficulty, moreover, of harvesting salt hay by machinery, would tend to make its cost, as compared with the cost of upland hay, relatively higher, in proportion to its worth, than was the case when all kinds of hay were made by hand; though it would seem, at first sight, as if all such considerations as this must be more than offset by the fact that the salt marshes are really water-meadows, whose fertility is incessantly renewed by the sea. They stand in no need of manuring or of tillage, but yield continually their crops of hay and of peat, at the mere cost of harvesting and of ditching.

The hardy cattle of the last century were probably rather better fitted to deal with the coarser kinds of food than the somewhat improved stock of the present day. But in any event it is to be observed that the coarse hays, whether salt or fresh, were not ill adapted for the purposes to which they were applied, when the object of the farmer was simply to maintain his cattle, without seeking to obtain from them any appreciable amount either of milk, or of flesh, or of work.

In view of all these considerations, it would seem that both the esteem in which salt-marsh hay was formerly held, and the present disfavor with which it is regarded, have really been based, in the main, on true and legitimate grounds. It will be seen that the analysis of rush salt grass, which constitutes the main burden of sea-marshes, does not indicate that our farmers have erred very much in renouncing the old opinion of its worth. It has been shown, already, that the results of the analyses are in accord with the popular conviction that black-grass hay, and in general the hay from brackish marshes, is better fodder than the hay of the rush salt grass that grows upon marshes which are more fully exposed to the sea. So far, indeed, as may be judged

from the small number of analyses here reported, the quality of the last-named hay seems to be inferior to that of ordinary bog hay. The remarks of Sprengel* upon the nutritive value of black grass show that, in respect to that particular grass, European experience agrees with that of this country. The sea spear-grass is classed among meadow grasses of the first quality by European writers. The analysis of Lehmann, cited on page 344, seems to show that, under favorable circumstances, the value of the hay from brackish marshes may be fully equal to that of an equal weight of the best upland hay.

It will be noticed that several of the analyses, particularly those of the bog hays, enforce the lesson, well known before, that even the coarsest kinds of fodder may be injured very appreciably by bad treatment, in respect to the time of mowing.

I have found it difficult to base any just estimate of the foddering value of bog hay upon the recorded experience of our farmers, although a good deal of that kind of evidence has been published. As early as the beginning of this century, the Trustees of the Massachusetts Society for Promoting Agriculture, "with a view to collect the most accurate information on the principal branches of agriculture as now practised," propounded certain "inquiries," among which were the following: —

No. XIX. "What is the proportion of value which Fresh-Meadow hay bears to Upland hay, each being of a medium quality?" And

No. VII. "What is the quantity and value of the Straw on an acre of barley, rye, oats, and wheat, respectively? And to how much Upland hay are they respectively equivalent for Fodder?"

The answers to these questions, that were gradually returned from different parts of the State, varied very much, as will be seen from the following citations: —

In a "Summary of [many] Replies hitherto received by the Society," that was published in 1807,† it is stated that, "In general, the comparative value of meadow to that of upland hay is said to be one-half; by the Western Middlesex Husbandmen, the former is thought to be one-third part as good as the latter; and Colonel P., of New Gloucester, thinks it is near two-thirds, especially if it is salted when first stowed in the barn, and where salt hay is not to be had."

* Erdmann's "Journal tech. und œk. Chemie," 1829, 5. pp. 60, 295.

† Papers published by the Trustees of the Society, 1807, pp. 10, 30.

Some years later the question was again answered, as follows: From West Springfield:* "The proportion of value which fresh-meadow hay bears to upland hay, each being of a medium quality, is about two-thirds."

From Newbury:† "About two-fifths."

From Vassalborough:‡ "Meadow hay is worth about half its weight of upland hay."

From Danvers:§ "About one-third."

From Dunstable:|| "Proportion of value as one to three."

In 1823, Mr. Prince,¶ of Roxbury, complains of the "too general practice of feeding cows in the winter with only meadow hay which has less nourishment than good straw," and the complaint has often been repeated since then. The unreasonableness of assertions so sweeping as this is well shown by the following remark of Dr. Sturtevant, of Framingham, made in the course of a recent debate on Dairy Husbandry.**

"The farms in Massachusetts contain a great variety of soil, and some of it is pretty bad. In one location in eastern Massachusetts, I know of a farm which would support nothing like the number of stock that are kept on it, from the good land of that farm. The only way we can carry the herd, and make it profitable, is by utilizing the poor hay and poor land of that farm. At the present time on our own farm we are keeping a breeding herd of about thirty-two cattle, all told. We have one foddering of hay, and one foddering of the low-meadow hay. At the present time, we are feeding what we in Massachusetts call meadow hay (that is, muck-land hay), mixed with a quart and a half or two quarts of grain a day to each cow, either shorts or meal. In Massachusetts we cannot feed all good grass, because we haven't it. If we undertook to do it, we should have to cut down our herds about two-thirds."

At the present time, February, 1875, bog hay or "swale hay," as it is sometimes called, sells in the Boston market at $12 @ 13 per ton, the price of the best upland hay being $22 @ 23, and that of medium upland hay $19 @ 20. But the city price hardly bears upon the question of fodder value, since the bog hay is not used here as food to any extent, but somewhat for bedding animals and largely for packing crockery and glass-ware. In point of fact, the bog hay is worth decidedly less in the Boston market than straw, which is esteemed to be cheap at the price for which it is now selling; viz., at $17 @ 18 per ton.

* The "Massachusetts Agricultural Repository and Journal," 1815, **3.** 59.

† Ibid. 1815, **3.** 263.

‡ Ibid.

§ Ibid. 1815, **3.** 341.

|| Ibid. 1815, **4.** 48.

¶ Ibid. 1823, **7.** 168.

** See Massachusetts Agricultural Reports, 1872, p. 48.

From Connecticut,* Mr. E. H. Brown, of Gilead, reports that in his vicinity "swamp hay sells for bedding for about one-third the price of upland." Mr. H. Holmes, of Stafford Springs, quotes the local price of best upland hay at $25 per ton, and that of coarse meadow hay at $10; and Mr. William Ross, of Chaplin, says that "good upland hay is worth more than double the price of bog hay for the feeding of all kinds of stock."

As has been said already, it will be necessary, in order to a just estimate of the foddering value of bog hay, to contrast it with the coarser kinds of forage, such as straw, as well as with upland hay. As evidence bearing upon this side of the question may be cited a number of answers to the last part of question No. 7 of the Massachusetts Society; viz., To how much upland hay are the several kinds of straws respectively equivalent for fodder?

From Worcester: † "A load of oat or barley straw is esteemed equivalent to a load of common meadow hay."

The Middlesex Society † "estimate the value of rye and barley straw as about one-tenth that of upland hay. Oat-straw is valued at three-sixteenths parts of common upland hay."

From Brookfield: † "Barley, rye, and wheat straw are equivalent to one-fourth of their weight of upland hay, and oat-straw to one-third."

From Brooklyn: † "Three hundred of barley and oat straw are estimated equal to four hundred of upland hay [*sic*]. Of rye and wheat straw four hundred weight are equivalent to one hundred of upland hay."

From Newbury: † "The value of barley straw is thought equivalent to half its weight of upland hay. The straw of other grain is of small value, except for litter."

From Marlborough: † "Mr. Packard considers rye and wheat straw as equally valuable as fodder, and that the produce of an acre of either of them is worth four hundred weight of upland hay."

From West Springfield: ‡ "Barley, oat, and wheat straw are equivalent to one-sixth or one-eighth their quantity of upland hay for fodder; rye straw from one eighth to one-twelfth."

From Shrewsbury: ‡ "Barley and oat straw may be equivalent to one-half the quantity of upland hay, and wheat straw to one-third. Rye straw is worth but little for fodder."

From Vassalborough: ‡ "Straw, except oat, is seldom used for fodder. Oat-straw is equal to half its weight of good upland hay."

* "Report of Sec. Connecticut Board of Agriculture," 1868, pp. 119, 134, 156.
† Papers, 1807, pp. 19, 20.
‡ Mass. Repository and Journal, 1815, **3.** pp. 57, 117, 261.

From Danvers: * "The straw of barley and oats is equivalent to one-third the quantity of upland hay."

From Dunstable: † "Rye-straw is little esteemed for fodder. Oat-straw is equivalent to one-fourth or one-sixth its quantity of upland hay for fodder."

These loose and conflicting surmises are interesting, inasmuch as they serve to show how small an advance towards any real and definite conclusion as to the fodder-worth of straw had been made by our farmers at that time. Although it can hardly be said that the general tenor of the statements is in accord either with the results of analysis or with the foddering practices of the country, it will nevertheless be noticed that a large part of the answers do agree with these evidences in ranking bog hay decidedly above straw, and so lend to them a certain share of support.

In the light of the evidence thus far presented, there can indeed be little doubt but that our salt and fresh hays possess considerable value as fodder. They constitute one important resource for the farmers of New England, which will doubtless be availed of in the future as in the past, and the more fully in proportion as their real significance is more clearly understood. There are few more interesting problems for the farmers of any region to work out than those which relate to the judicious utilization of the comparatively speaking innutritious kinds of food that are produced upon the farm, and which are too coarse and bulky to be merchantable. Such problems have lost much of their former difficulty in these days of cheap transportation, when, besides the old resource of root crops, grain, bran-feed, cotton-seed meal, and other waste products may be bought almost everywhere; and they are of course specially easy when the rough forage is in itself fairly good, as the bog and salt hays appear to be when contrasted with the straw that is so large a component of many of the fodder mixtures of Europe.

It would seem to be plain that there are many places in New England where it would be not merely a good practice, but really excellent farming, to feed out upon the farm the hay from coarse, natural herbage, with the addition of small quantities of some of the concentrated forms of food, and to send off the farm, in so far as might be practicable, the more costly upland hay, to be marketed like any other merchantable

* Mass. Repository and Journal, 1815, **3.** 339.

† Ibid., 1815, **4.** 46.

product. It must often be true, all things considered, that for home use the rough, low-grade hays are actually better fodder than English hay.

I am far from seeking to deter any farmer (or combination of farmers) from embanking his salt marshes or from draining his boggy meadows when his circumstances and the conditions of his land are favorable for improvements such as these. There has never been any question but that the agricultural product of New England might be enormously increased, if but a fraction of the wild low land in that country which is susceptible of improvement were subdued. But the consideration of the importance and general desirability of those improvements should not be permitted to conceal the fact that the natural products of the wet lands are by no means wholly worthless. Whatever value these products do really possess, be it large or small, should be clearly recognized and allowed for, and put to use.

My thanks are due to my assistant, Mr. D. S. Lewis, for his skilful co-operation in this research, and the one described in the next article also.

No. 17. — *On the Fodder Value of Apples.* By F. H. Storer, Professor of Agricultural Chemistry.

The precise significance of apples as food for animals does not appear to have been ever very clearly made out. Though eaten greedily by all kinds of cattle, this fruit is seldom given to them purposely, or in a methodical way; and, although it often happens here in New England that horned cattle in particular have access to windfall apples in their pastures, in such wise that they actually consume very considerable quantities of them, there are comparatively few farmers who would deem it good practice to feed out apples to stock as they would feed pumpkins, or turnips and other roots.

It is evident that a certain prejudice against the use of apples, as cattle food, prevails among farmers almost everywhere. Sometimes the objection is raised that there is "no nourishment in apples;" at other times it is asserted that they are "too sour," and that they will "dry off milch cows." We sometimes hear that they are apt to choke the animals, and at others that the trouble of collecting them would be greater than their worth. Against the last four objections it might be urged, that there is manifestly no need of feeding out apples injudiciously, and that we have daily evidence that cattle can eat moderate quantities of this fruit, even the sourest kinds, without injury to their health or their efficiency; that, as with turnips, the risk of choking may be avoided by either cutting, crushing, or cooking the fruit before giving it to the animals; and that, in the case of windfalls, at least, the trouble of collecting the apples would be partly offset by the fact that the process could be made to serve, incidentally, as a means of destroying the grubs in the apples, which have caused them to fall.

As for the question, How much nourishment the apples really contain? that can only be answered by way of analysis, and by careful and judicious experiments in feeding animals. But, as will appear below, the composition of apples is so little like that of the roots and herbs ordinarily used as fodder that it was really no easy matter to try conclusive experiments with them before this composition had been found out. In the absence of any just knowledge of the constituents of a given fodder, it is, of course, difficult to determine what kinds of

food should be given in connection with it, in order that its components may be properly utilized by the animals. It is not surprising, therefore, that so many doubts and uncertainties should have prevailed hitherto with regard to the fodder value of this fruit.

It is true that a number of analyses of apples, and of other kinds of fruits, made several years since by Fresenius,* have been cited by Professor Johnson, in his work entitled "How Crops Grow," New York, 1868, pages 392, 393; but the purpose of these analyses, the manner in which they were made, and the way in which the results are stated, were all so unlike the purpose and methods which apply to the usual analyses of foddering materials, that it was not easy to contrast † Fresenius's results with those obtained by the chemists who have made analyses of hay, grain, roots, and the like.

With the view of obtaining data which should enable any one to translate the results of Fresenius into the usual language of agricultural chemists, I have had made the following analyses of the flesh and skin of apples, and of the residue, known as pomace, which is left in the cider-press after the juice of the apples has been squeezed out, — all according to the method now in common use, as cited on page 26 of this Bulletin.

I. Flesh of the common red "Baldwin" apple of New England. The apples taken for analysis grew upon a gravel knoll about half a mile from the Bussey Institution. They were of medium size, sound, and fair, had been carefully stored, and were in excellent condition when subjected to analysis in the middle of February, 1875. Both the skins and cores of the fruit were rejected in preparing the sample for analysis.

II. Flesh of the common Roxbury russet. The fruit grew in Jamaica Plain in the immediate vicinity of the Bussey Institution. The apples taken for analysis were large, fair, and in excellent condition. The skins and cores were carefully removed, and only the flesh proper was taken for the analysis.

III. Parings of the Baldwin apples described in No. I. The

* "Annalen der Chemie und Pharmacie," 1857, **101.** 219.

† It is but fair, however, to say that the comparison has been made, and that very justly, by Professor Alexander Müller, in his chart entitled, "Die chemische Zusammensetzung der Nahrungsmittel und Futterstoffe." Dresden: 1861.

apples were first gently pressed, or rather kneaded, with the finger, in order to loosen the skin from the flesh; they were then pared in narrow strips with a sharp knife, and whatever of the flesh still remained adhering to the skin was carefully scraped off, so that a tolerably clean product was finally obtained. It is to be remarked that the weight of parings thus thoroughly freed from flesh is very small, as compared with the weight of the entire apple.

IV. Parings of the russet apples described in No. II. In order to detach the closely adhering skins of the russets in sufficient quantity for an analysis, it was found to be necessary to heat the apples for a short time to about 80° C. After the fruit had been thus heated, it was easy to peel off its skin in a perfectly clean condition. But since it would have been impossible to determine, in parings thus obtained, how much moisture is contained in the skin of the russet, a special small sample was procured for that purpose from the original unheated apples by simply paring the cold fruit and scraping the skin, much in the same way that the Baldwin parings were obtained, as described in No. III.

V. Pomace obtained Oct. 24, 1874, in a fresh condition, from Mr. S. W. Whittemore, of West Roxbury. The apples from which this pomace was made were sound Baldwins mixed with a few sweets; they were mellow and were powdered in a grater mill. The cheese was squeezed in an old hand-press that was not very efficient. The yield of juice was between 3¾ and 4 gallons to the bushel of fruit. No water was added to the ground apples except a single pailful "to wash the mill."

A determination of moisture was immediately made in the fresh pomace, while another large quantity of it was dried down rapidly with constant stirring, upon the water-bath, in order to prevent fermentation. The hard, dry particles, which resulted from this treatment, were ground to a fine powder in a drug-mill, and the powder was thoroughly mixed, so that an excellent average sample of the pomace was obtained for the analysis. As thus dried the pomace still retained 9.78% of water that could be driven off at 110° C. The results stated below have, of course, been calculated back from those actually found, in order to make them consist with the 77.21% of moisture that was found in the fresh pomace.

The results of the analyses are as follows: —

	I. Baldwin. Flesh.	II. Russet. Flesh.	III. Baldwin. Skin.	IV. Russet. Skin.	V. Pomace.
Water (at 110° C.) . . .	84.11	82 22	71 60	69.93	77.21
Ash free from C & CO_2)	0.23	0.26	0 45	0.53	0.50
Albuminoids	0.21	0 27	1.00	1.08	0.98
Carbohydrates (including fat)	14.54	16.30	21.58	23.44	17.41
Cellulose (free from ash) .	0.91	0.95	5.37	5.02	3.90
	100 00	100.00			100.00
Dry organic matter . .	15.66	17.52	27 95	29.54	22.29
Fat (*i.e.*, ether extract) .	0.28*(?)	0.53*	2.27	1.71	1.70
Nitrogen	0.032 — 0.035	0.043 — 0.043	0.158 — 0.162	0.168 — 0.177	0.155 —0.159
Crude ash	0.26	0.31	0 59	0 68	0.51†

The results of these analyses agree closely with those of previous observers, in so far as the latter admit of being compared with them. Thus, in respect to water, Schulze ‡ found the following percentages in as many different kinds of entire apples from Rostock, in the north of Germany: 86.45, — 86.55, — 85.56, — 85.16, — 86.62, — 85.97, — 84:34, — 83.59, — 82.59, — 87.07, — 80.32, — 84.69, — 78.90, — 84.30, — 86.27, — 83.72, — 85.94, — 84.13, — 84.63, — 85.52, and 84.30. The maximum of dry substance found by Schulze in any one kind of apple was 21.10%, and the minimum 12.93. Wolff § found 83.58, — 83.06, — 82.76, — 83.75, — 85.97, — 85.95, — 86.27,

* It is not probable that the apparent difference between the amounts of "fat" in the flesh of russet and Baldwin apples, as stated above, is based upon any real dissimilarity in the amounts of this constituent in the two varieties of the fruit. The discrepancy in the table is doubtless due to the fact that different analytical methods were employed in the two cases for the estimation of the ether extract. During the treatment of the dried apple flesh with ether, it was noticed, in both instances, that a considerable quantity of a reddish substance separated from the extract before the latter was evaporated. This precipitate was so little soluble in cold ether that it was at first thought to be insoluble, and was purposely removed for the most part from the ether extract obtained from the flesh of Baldwin apples. But since it appeared afterwards that the substance could be dissolved by the long-continued action of ether at the ordinary temperature, applied in successive portions, it was thought best to weigh it with the rest of the ether extract in the analysis of the russet flesh.

It should be said, in general, that the dried ethereal extracts, obtained both from apple-flesh and from apple-skin, are of peculiar appearance. They evidently contain much resin and wax, as well as fat. They are friable, for the most part, and they do not melt at the temperature of boiling brine. When heated on platinum foil they burn like a mixture of fat and resin.

† Another determination gave 0.55% of crude ash.

‡ "Journal für praktische Chemie," 1854, **62.** 213.

§ Cited in Henneberg & Kraut's "Jahresbericht für 1855, 1856," pp. 177, 178.

and 86.60% of water in eight different kinds of apples from Wurtemberg: and Fresenius found 86.03, — 82.03, — 82.04, — 85.04, — 82.49, — 82.13, and 81.87% of water in five different kinds of apples, apparently from the vicinity of Wiesbaden, the first three determinations in his list having been made upon one and the same kind of apple grown in three different years. Whence it appears that the average amount of water in whole apples — flesh, skin, seeds, and core together — is 84.14%.

In respect to crude ash,* Richardson found 0.27% of it in fresh apples; Margold found 0.46, — 0.26, and 0.38%; and Fresenius, 0.28, — 0.39, and 0.47%, — the entire fruit having been burned in each instance. In air-dried pomace Gasparin † reports 0.59% of nitrogen, and in that which has been "dried completely" (perhaps at 100°?) 0.63%. The sample of pomace analyzed in this laboratory, when dried at 110° C., contained 0.70% of nitrogen.

It is of interest to note the fact that both Wolff and Fresenius find that much the larger part of the solid substance of ripe apples is soluble in water. Thus in the eight analyses of Wolff the sum total of soluble constituents was 13.67, — 14.49, — 13.23, — 13.58, — 12.06, — 11.26, — 11.27, and 10.45% of the weight of the entire apple, and the weight of the insoluble residue was 2.75, — 2.45, — 4.01, ‡ — 2.67, — 1.97, — 2.79, — 2.46, and 2.95. In the seven analyses, reported by Fresenius, the sum of the soluble constituents was respectively 11.58, — 14.70, — 14.96, — 12.00, — 15.07, — 13.34, and 15.95%, while the amount of the insoluble components was 2.39, — 3.27, — 3.00, — 2.96, — 2.44, — 4.53, and 2.18.

The most noteworthy feature in the composition of the apple is the very small proportion of albuminoids that are contained in it, as compared with the amount of carbohydrates. This fact may readily be made manifest by comparing the analyses of the flesh of the apple, as above given, with the composition of the various roots enumerated in the table on page 387 of Johnson's "How Crops Grow." Or it may be illustrated still more forcibly, perhaps, by throwing the item moisture (*i.e.*, "water"), out of the account, and contrasting the percentage

* As has been already stated on page 208 of this Bulletin.

† In his "Cours d'Agriculture," 3me edition, 1. 579.

‡ The apples, in this particular instance, were not fully ripe.

composition of the dry matter in the flesh of the apple with the dry matter in various roots (and in the pumpkin), as has been done in the following table: — *

	Albuminoids.	Carbohydrates, including Fat.	Cellulose.	Ash (free from C & CO_2).	The proportion of dry matter (including Ash) in the fresh material is —
Potato	8.54	84.22	2.83	4.41	25.39
Jerusalem Artichoke . .	10.04	79.72	4.70	5.54	19.12
Sugar Beet	5.52	82.10	7.54	4.84	17.75
Field Beet	8.90	75.78	8.07	7.25	13.36
Carrot	8.17	74.39	10.35	7.09	15.63
Ruta Baga	9.92	73.86	9.49	6.73	11.59
White Turnip	9.40	69.44	11.76	9.40	8.50
Parsnip	13 67	71 81	8.54	5.98	11.70
Pumpkin	17.32	56.02	13.33	13.33	7.50
Flesh of Apple†	1.43	91.59	5.54	1.46	16.84
Pomace	4.30	76.39	17.11	2.19	22.79

The practical conclusion to be drawn from these comparisons seems plain. The exceedingly small proportion of nitrogen in the apple, indicates very clearly the necessity of using, in conjunction with this fruit, some kind of fodder that is exceptionally rich in nitrogenous constituents; such, for example, as greaves, or flesh-meal, or fish-scrap (that has been carefully cured), peas, beans, oil-cake, or the like. I have myself witnessed, many years since, some highly favorable results, that were obtained by feeding a herd of fifteen or twenty swine with a mash made of the sourest native cider apples, and the meal of mixed peas and oats. In this instance, the apples were boiled thoroughly in large kettles, whence they were shovelled into hogsheads, where a small proportion of the meal was sprinkled upon each layer of the hot mass, and left where it fell for awhile, in order that it might be cooked, before the whole was stirred to a homogeneous mixture. The oats and peas had been grown together, and threshed and ground as if the harvest had been oats alone. The swine, which were from a

* Copied from Dietrich and Kœnig's "Zusammensetzung und Verdaulichkeit der Futterstoffe," Berlin, 1874, p. 78.

† Mean of the two analyses reported on page 365.

year to a year and a half old, had been maintained upon rather short allowance during the summer by means of swill from a tavern, together with what grain and straw they picked up in the manure of the tavern stable beneath which they were kept. The locality was among the foot-hills of the White Mountain range in New Hampshire, where the summer is tolerably short, and where maize, though grown abundantly, costs the farmer rather more in terms of trouble and anxiety than either oats or peas.

When put upon the apple ration, just described, these large and hungry * swine not only ate the mash voraciously, but they immediately began to grow with surprising rapidity, and they continued to prosper during the subsequent month or six weeks they remained under my observation. I am ignorant whether the fattening was finished upon the apple ration, or whether the hogs may not finally have been fed for a while upon maize.

Buckwheat bran (not buckwheat husks), a substance tolerably rich in nitrogen,† which, according to Johnston, of Durham,‡ is greatly approved of for feeding pigs in certain parts of New Brunswick, is another kind of food which might perhaps be used with advantage in conjunction with apples in some localities.

Statements of the successful use of apples, for feeding both cows and pigs, are occasionally made in the agricultural journals of this country,§ and it was doubtless the reading of these accounts, or the observation, during his travels in this country, of some of the infrequent examples which they describe that led Johnston, of Durham,‖

* It is worthy of remark that, in trying to repeat this experiment the next year, near Boston, upon a single pig, six or eight months old, that had always been kept well fed in a sty by itself, and had, consequently, never known want, or felt the need of haste in eating, the animal absolutely refused to eat a mash made of boiled greening and russet apples and corn meal.

† It contains from 15 to 18% of albuminoids, according to the analyses reported by Dietrich and König in their work entitled, "Zusammensetzung und Verdaulichkeit der Futterstoffe," Berlin, 1874.

‡ In his "Notes on North America," Boston, 1851, **2.** pp. 87, 128.

§ See, for example, the following instances, which have been taken quite at random: Fessenden's "New England Farmer," 1826, **4.** 125; "Transactions Essex Agricultural Society," 1835, p. 33; 1839, pp. 16, 17; 1846, p. 29; Colman's "Fourth Report of the Agriculture of Massachusetts," 1841, pp. 123, 326; "Transactions of Connecticut State Agricultural Society," 1856, p. 274.

‖ In his "Catechism of Agricultural Chemistry and Geology," Edinburgh, 1856, p. 60.

to make the rather broad statement that "apples are much used in some parts of the United States for feeding milk-cows and pigs, and are reckoned about equal to their own weight of potatoes."

In the light of the analyses, above recorded, it seems hardly probable that the mixed ration of corn meal and apples, or of "cob meal" and apples, described in the statements just referred to, is a specially judicious one, though it has probably been employed in this country more frequently than any other by experimenters on apples, and may be regarded in some sense as the basis upon which existing opinions as to the fodder value of this fruit mainly rest.

With regard to the comparative fodder value of apples and potatoes, that can only be determined by competitive trials, in which each of these kinds of foods is supplemented by other kinds that are competent to supply the constituents which are lacking in the apples or in the potatoes, as the case may be. From the analyses it would appear that there is actually less food in a pound of apples than in a pound of potatoes. The carbohydrates of the potato, moreover, consist largely of starch, which is a food of approved value. The significance of starch is so well understood almost everywhere at the present time, that its merits are no longer liable to be seriously called in question. But while it is true that the functions and value of starch are known more precisely than those of any of the constituents of the apple, excepting the sugar and fat, it would be wrong to suppose that apples can have no value as fodder because they contain little or no starch; for the pectose, pectin, and allied matters that constitute a large proportion of the carbohydrates of the apple are unquestionably useful forms of food when used judiciously, as well as the sugar that is contained to the extent of from 7 to 9% in apple juice.* It is a matter of the commonest experience that pumpkins and turnips and other roots, which contain much pectose, are to be classed as highly valuable forms of fodder; and it has been shown by the experiment of Grouven,† that pectin, which had been prepared for the purpose, and administered as such, was completely and rapidly digested by oxen.

In so far as concerns the amounts of starch, pectose, and pectin,

* As determined by Wolff, "Henneberg & Kraut's Jahresbericht für 1855 und 1856," p. 178; and by Fresenius "Annalen Chemie und Pharmacie," 1857, **101.** 232.

† Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1864, **7.** 301.

which they severally contain, it would be more reasonable to contrast apples with turnips than with potatoes; though, as has been shown already, the remarkably small proportion of nitrogen in the apple distinguishes it clearly from the turnip and allied roots, as well as from most other kinds of fodder.

The only kind of fodder equally poor in nitrogen which has fallen under my notice, is the curious edible fungus known as *tuckahoe*, or Indian bread (*Pachyma Cocos*), which grows in our Southern Atlantic States, beneath the surface of the ground, and which is said to be sought for and eaten by hogs,* as well as by the Indians and by negroes. A specimen of this fungus was analyzed in the laboratory of the Bussey Institution in the winter of 1874–75, according to the method usually employed for the analysis of fodder, as cited above. The sample in question consisted of a number of good-sized, sound pieces of the substance, selected from the Curtis collection of fungi. The dark-colored cortical portion of the fungus was cut off and rejected, and the internal white matter was ground to fine powder and thoroughly mixed.

The results of this analysis were as follows: —

	In the air-dried sample.	In the "dry substance" of the tuckahoe.
Water (at 110° C.)	14.51	....
Ash (free from C & CO_2)	0.24	0.28
Albuminoids	1.38	1.61
Carbohydrates (including fat)	74.07	86.64
Cellulose † (free from ash)	9.80	11.47
	100.00	100.00
Dry organic matter	85.25 plus ash =	85.49
Fat	0.34	
Nitrogen	0.200 — 0.242	
Crude ash	0.24	

* C. W. Johnson's "Farmer's and Planter's Encyclopædia of Rural Affairs," adapted to the United States, by Gouverneur Emerson, 1855, p. 1056.

This fungus is found in the northern part of China also, and is there largely used as a drug and an esculent. See "American Journal of Science," 1859, **27.** 438.

† The substance here recorded as cellulose, which was, of course, the residual matter that had resisted the action of weak acid and alkali, applied in the usual methodical way for the purpose of removing carbohydrates and albuminoids, differed in appearance and somewhat in behavior from that ordinarily obtained from fruits and herbs. While yet moist, the tuckahoe cellulose was a voluminous white pulp, but on drying it shrunk to a dark, tough, horn-like mass. On boiling a quantity of the product prepared by the analytical process with fresh por-

The results of this analysis are remarkably different from those obtained by the chemists who have examined ordinary fungi, such as mushrooms and toadstools, which show a large proportion of nitrogen and of ash. See, for example, the memoir of Schlossberger & Doepping in "Annalen der Chemie and Pharmacie," 1844, **52**. 106.

It would appear from the analysis made long ago by Torrey * that the tuckahoe consists for the most part of pectose, or a substance of similar properties, and that it contains very little, if any, sugar or starch or gluten. It seemed to Dr. Torrey "a very remarkable circumstance that an entire vegetable, in a dried state, should consist almost exclusively of one proximate principle."

With regard to the composition of the apple, however, it should be said that it is not very unlike that of some other fruits. Analyses of other kinds of fruits that have been made by Fresenius, in the place above cited, go to show that a few of them, such as pears, and some kinds of plums, contain no more nitrogen than the apple.

The analysis of pomace, and the statement of the composition of the dry matter, contained in it, indicate some of the reasons why this substance has been held in such small estimation hitherto, either as fodder or as manure. Thus Marshall † long ago remarked that pomace "is considered of little value as manure (but I know not why)." He had, of course, no means of ascertaining, what the analysis clearly shows, that pomace actually contains only a very small proportion of matters that are useful as food for plants. There are, indeed, few vegetable substances likely to be used as manure that contain so small a proportion of nitrogen and of ashes as pomace. The common opinion of our farmers that pomace has scarcely any fertilizing power,

tions of the dilute potash lye, it appeared that scarcely any of it dissolved in that liquid. When tested with iodine and sulphuric acid, it did not give any blue coloration such as was readily obtained with cellulose that had been prepared from apples, potatoes, buttercups, and filter paper. In this connection a remark of Schlossberger in his "Lehrbuch der organischen Chemie," Leipzig, p. 85, may be cited: "The membrane of yeast cells and the cell walls of fungi appear to be identical with ordinary cellulose, though it has not been observed that they give the blue reaction with iodine [after acid]." Compare the analyses of cellulose from fungi, and other sources, in Gmelin's "Handbook of Chemistry," **15.** pp. 129–133.

* "Medical Repository," New York, 1821, **6.** 37, and "New York Medical and Physical Journal," 1827, **6.** 484. It is remarkable that this careful research of Torrey seems never to have been noticed either by investigators of pectous substances, or by the compilers of the chemical cyclopædias now in common use.

† In his "Rural Economy of Glocestershire," 1796, **2.** 310.

except in so far as it may be made useful for mulching, is clearly a correct opinion.

In respect to the fodder value of pomace it may be said to resemble that of apples, on the whole, and to demand the same kinds of additions. Since the proportion of albuminoids in pomace, though higher than in the apple, is still very low, there is manifest need of mixing with the pomace some kind of highly nitrogenized food, such as fish-scrap (as was said before) and fleshmeal that have been prepared expressly for feeding animals. It cannot be too strongly insisted that both these materials are intrinsically much too valuable to be used directly as manure. There can hardly be room to doubt that it would be much more advantageous for all parties concerned if both the fish and the flesh were prepared and used as cattle food. It is to be observed, however, that pomace is a decidedly coarser kind of food than apples, and that it is consequently less generally applicable than the latter. It would seem, nevertheless, to have a distinct and definite value as fodder, and to be well worth the trouble of saving for that purpose. It would be interesting to determine by actual trial whether, beside the ordinary method of drying, a process of preservation which is largely employed in Europe for keeping a variety of soft and juicy materials, and particularly those which cannot easily be dried, might not be available for the preservation of pomace. The so-called "sour hay" or "sour fodder," which results from the process of incipient fermentation now in question, may be made from the refuse of potato-starch works, from the residue of the sugar-beet root after the juice has been expressed, from frozen potatoes or other roots, as well as from beet leaves, fodder corn, and other succulent herbage. The trouble of preparation is small; the sour fodder is greedily eaten by cattle, and it may be kept even until spring without harm.

The small amount of nitrogen and of ash in the apple shows how little an orchard of this fruit would tend to exhaust the land, provided the conditions were such that the leaves falling from the trees could be retained upon the ground beneath. An analysis of apple ash, by Richardson, cited on page 208 of this Bulletin, shows that a thousand pounds of fresh apples would carry off no more than eight-tenths of a pound of potash and one-third of a pound of phosphoric acid.

No. 18. — *On the Composition of Date Stones; and of the Stones of Peaches and Prunes.* By F. H. Storer, Professor of Agricultural Chemistry.

It is a matter of familiar observation that the stones of the ordinary edible date, from the palm *Phœnix dactylifera*, are extremely tough and hard, and that their outward appearance gives little indication that they possess any value as food. Yet it is well known through the reports of travellers that date stones are often employed as fodder by the Arabs. Thus, for example, Burckhardt * states that "The people of the Hedjaz, like the Egyptians, make use of the leaves, the outer and inner bark of the trunk [etc., of the date palm]; and, besides this, they use the kernels of the fruit as food for their cattle: they soak them for two days in water, when they become softened, and then give them to camels, cows, and sheep instead of barley; and they are said to be much more nutritive than that grain. There are shops at Medina in which nothing else is sold but date-kernels; and the beggars are continually employed in all the main streets in picking up those that are thrown away. In the province of Nedjed the Arabs grind the kernels, for the same purpose; but this is not done in the Hedjaz."

So, too, Richardson † remarks that "The very stones [of the date-palm] are split and pounded to fatten all animals here" [at Ghademes in the Sahara].

It has occurred to me that an important lesson for those farmers who have not yet familiarized themselves with the significance of chemical analysis as a means of indicating the values of fodders might be drawn from the analysis of date stones, since it would be hard to find any other substance equally familiar whose outward appearance gives so little promise of its real worth. There are probably very few things used as fodder that are so little likely to be understood or valued aright if one were to judge from appearances merely.

For the sake of contrast I have had analyses made of peach and prune stones also: that is to say, of the hard covering or shell of the

* Burckhardt, J. L., "Travels in Arabia." London, 1829, **2.** pp. 211, 212.

† Richardson, James, "Travels in the Great Desert of Sahara." London, 1848, **1.** 343.

kernels of peaches and French prunes. Each of the analyses has, of course, a certain value for its own sake, in that it adds one new item to the lists of analyses of fodders from different countries that have been gradually accumulated by chemists.

The character of the materials examined and the results of the analyses will appear from the following statements: —

I. Date stones taken from a sample of light-colored dates, called "sugar-cured," by the grocers.

II. Date stones taken from a sample of the ordinary dark-colored dates, said to be "molasses cured." The dates of both Nos. I. and II. were in the usual pressed or impacted condition in which they are brought to this country in the so-called frails, or bags of basket-work.

The flesh of the dates was completely removed from the stones in both instances, before the latter were prepared for analysis. It was found to be a very difficult matter to reduce the tough date stones to powder fine enough for an analysis. On pounding in a steel mortar the coarse grains obtained by the use of a drug mill each grain would be completely flattened under the pestle. It was only by repeatedly grinding, pounding, and sifting the material that the whole of it was finally reduced to the condition of a tolerably fine powder.

III. Peach stones; that is to say, the hard part, or shell, of the kernel of the peach. The substance analyzed was a mixture of shells from two kinds of peaches obtained in this vicinity early in October, 1874. The flesh of the peaches was carefully removed by rubbing and washing the stones. The proportion of hard external shell to the soft internal "meat" of the kernel was found, in March, 1875, to be as 90.82% is to 9.18% in the one kind; and as 92.63% is to 7.37% in the other. It had been noticed that the peaches of the last-named sort were less palatable than the others.

IV. Prune stones; that is to say, the hard part or shell of the kernels of dried (but uncooked) French prunes from which the external fleshy part of the fruit had been completely removed by rubbing and washing. The relative weights of the hard shell and the soft "meat" within the shell were as 74.3% is to 25.7%.

	I. Date Stones.	II. Date Stones.	Mean of the two Analyses.
Water	7.71	10.83	9.27
Ash (free from C and CO_2)	1.05	1.02	1.04
Albuminoids	5.16	5.75	5.46
Carbohydrates (including fat)	62.01	60.34	61.17
Cellulose (free from ash)	24.07	22.06	23.06
	100.00	100.00	100.00
Dry organic matter	91.24	88.15	89.70
Fat (ether extract)	8.95*	8.05*	8.50
Nitrogen	0.79—0.86	0.92	0.86
Crude ash	1.05	1.02	1.04*

	III. Peach Stones.	IV. Prune Stones.
Water	5.53	10.96
Ash (free from C & CO_2)	0.36	0.40
Albuminoids	0.58	0.31
Carbohydrates (including fat)	22.90	39.59
Cellulose (free from ash)	70.63	48.74
	100.00	100.00
Dry organic matter	94.11	88.64
Fat (ether extract)	0.09	0.72
Nitrogen	0 091—0.096	0.05
Crude ash	0.44	0.40

It will be seen at a glance, from the foregoing analyses, that the date stones are very much richer than the peach and prune shells in all three of the more important constituents of fodder ; namely, the albuminoids, the carbohydrates, and the fats. It is to be noticed, however, that this fact is neither surprising nor unexpected, for the compact date stone comprises both shell and kernel (*i.e.*, both stone and meat); while, in the case of the peach and prune stones, the shells alone were analyzed after the kernel proper had been carefully removed.

The composition of the date stones, as exhibited by the analyses, is really quite interesting, inasmuch as it differs decidedly from that of all the foddering materials that have been examined hitherto. The use of the date stones as fodder is explained and justified by the analyses, since it is made plain that they are rich in fat and in carbohydrates, and that they contain a fair proportion of albuminoids also, while they are by no means very highly charged with cellulose.

It will be seen from the following table † of the average composition

* The ethereal extract from the powdered date stones left, when dried, a remarkably pure fat. In both instances, the residue was a clear light-brown oil, that remained fluid at the ordinary temperature of the air.

† Copied, with some slight alterations, from Dietrich and Kœnig's "Zusammensetzung und Verdaulichkeit der Futterstoffe," Berlin, 1874, pp. 76.31.

DATE STONES CONTRASTED WITH OTHER FODDERS.

Name of the Fodder.	After moisture has been expelled by drying the fodder at 212° (F.), the *dry substance* contains per cent of: —					The per cent of dry substance in the undried fodder was,
	Ash.	Albuminoids.	Carbohydrates, including fat.	Cellulose.	Fat.	
Date Stones (mean of the two analyses)	1.15	6.02	67.42	25.42	9.37	90.73
Olive Cake	7.83	6.97	46 55	38.65	15.23	86.24
Acorns, with their shells . . .	2.31	5.03	75.24	17.43	4.18	55.48
Chestnuts, with their shells . .	2.37	5.31	75.86	16.52	4.32	61.53
Shelled Chestnuts	2.43	6.36	85.65	5 56	4.73	76.04
Shelled Acorns	2 00	6.25	86.00	5.75	5.38	80.00
Barley	3.03	13.90	77.16	5.91	2.40	86.93
Wheat	1.94	14.55	81.11	2.40	1.78	86.84
Maize	2.81	11.33	81.05	4.81	6.33	87.62
Hay	7.65	11.82	50.68	29 85	2.73	85.41
Beet-root Cake, (from sugar-making)	10.86	6.76	62.59	19.79	1.48	28.23
Potato Pulp	1.44	4.89	79.63	14.04	0.86	13.89
Cabbage Stumps	10.54	6.10	67 82	15.54	1.66	18.00

of the dry substance in several kinds of fodders that the date stones bear a certain distant resemblance to chestnuts and acorns, and to the "oil cake" that is left on expressing the oil from olives, though the

resemblance is very slight at the best. It can be said merely that the date stones resemble these things more nearly than they resemble barley, wheat, and hay, and most other foddering materials. It will be noticed that there are several other substances — such as the refuse cake of the beet root, from which the juice has been expressed for making sugar; potato pulp left in the manufacture of starch; and cabbage stumps also — whose composition resembles that of date stones in one or two particulars, but which is clearly distinguished therefrom by the fact that the substances in question contain very little fat.

The unlikeness of the date stones to most of the ordinary fodders may be clearly seen by comparing the analyses given on the previous page with the tables of fodder analyses on pages 385–388 of Johnson's "How Crops Grow," New York, 1868.

No. 19. — *Analyses of Sundry Potassic Fertilizers, procurable in Boston.* By F. H. STORER, Professor of Agricultural Chemistry.

THE following list comprises a number of analyses that have been made from time to time in the Bussey laboratory since 1872. It may be regarded as a supplement to the article on wood ashes, which was printed a year or more ago on pages 191 to 251 of this Bulletin. Taken in connection with that article, it may serve to convey a tolerably clear idea of the amounts of potash that are contained in the fertilizers here obtainable, and to indicate those which are most worthy the attention of the farmers of New England.

I. A sample of Muriate of Potash taken from a ton or two of the substance that was obtained, in the autumn of 1872, from William Grange, of Baltimore, by Henry Saltonstall, Esq., of West Peabody, Mass. From the bill of sale it appears that the muriate was held to contain 83% of pure chloride of potassium, by the Baltimore dealer, and was sold at the rate of 2⅝ cents, gold, per pound on the basis of 80% pure chloride of potassium. The price was equal to $60, currency, per ton, as will appear directly.

II. A sample of Muriate of Potash taken from a lot of six tons bought in Boston in January, 1874, by John R. Brewer, Esq., of Hingham. This lot of muriate was said to contain about 85% of the pure chloride. Its price was $55, currency, per ton, on the basis of 80%.

The results of these analyses are as follows: —

	I.	II.
Moisture	1.29%	0.49
Sand	0.60	0.14
Real potash (K_2O)	52.94	52.80
[Or, chloride of potassium	83.80	83.58]

Beside the substances here enumerated, the article known in commerce as "80% muriate" contains some 12 or 15% of chloride of sodium and a small amount of chloride of magnesium. Compare Heiden's "Düngerlehre," Stuttgart, 1868, **2**. 381.

It will be seen that these analyses agree closely with the statements of the dealers from whom the fertilizers were bought. Like the anal-

yses of many other chemists, they bear emphatic witness to the general good quality of the Stassfurt muriate of potash of 80%. When the lot was purchased from which sample No. I. was taken, the price of gold was 114½; hence the cost of the muriate in terms of American currency was three cents per pound, which would be equivalent to nearly six cents per pound for real potash (K_2O). In sample No. II. the price of real potash was about 5½ cents per pound, as has been stated already in the note on page 185 of this Bulletin. In the spring of 1875, muriate of potash of 80% was sold at about three cents currency per pound in Boston, and at 2½ to 2¾ cents in New York. At the present time (November–December, 1875) it is worth 2¼ cents currency in New York, and can be brought thence to Boston for ¼ cent per pound.

III. A sample of so-called "Stassfurt potash salt," sent to Thomas Motley, Esq., at the Bussey Farm in May, 1873, by a Boston importer. The sample was said to have been drawn from several bags. The results of its analysis, given below, differed but little from those obtained on analyzing another sample, previously sent to Mr. Motley by the same dealer, that had been taken from a single bag.

IV. A sample of "Kainit," taken from a ton of the substance bought in May, 1873, of a Boston importer, by John R. Brewer, Esq., of Hingham. These samples contained, besides much chloride of sodium, an abundance of magnesium salts and some gypsum: —

	III.	IV.
Moisture	5.74%	7.53
Matters insoluble in water	6.08	5.54
Sulphuric acid	10.17	10.19
Real potash (K_2O)	11.42	10.59
[Or, calculated as sulphate of potash	21.12	19.58]

Considered as potassic manures, Nos. III. and IV. were manifestly greatly inferior to the samples of muriate (Nos. I. and II.) previously described. At $40 per ton, the price paid for No. IV., each pound of real potash would come to rather more than 18 cents, to say nothing of the cost of handling the 1600 pounds of useless matters in each ton of the fertilizer, or of the risk that some of these extraneous matters (magnesium and sodium salts) might actually injure the crops to which they were applied.

It is to be observed that, although the fertilizers numbered III. and IV. contain enough sulphuric acid to enable the dealers to speak of them as if their potash were in the form of a sulphate, they cannot justly be regarded by the farmer as sulphate of potash, or as possessing any quality which would tend to make them preferable to the muriate. They consist in reality of mixtures of the chlorides and sulphates of sodium, magnesium, and potassium, and are in every respect inferior to the high grade " muriate," or chloride of potassium, such as was described under Nos. I. and II.

The fact that the American market has for several years past been flooded with the lower grades of the Stassfurt fertilizers is a curious evil, that needs to be generally known, — and to be corrected. The higher grades are, of course, much better able to bear the costs of transportation, and should by good rights always be brought to us, as has been indicated in the note on page 185 of this Bulletin. I am informed, however, that the Stassfurt salts are imported for the most part in the vessels which are employed for carrying petroleum to Europe. Many of these vessels are old and of little value, and quite unfit for other uses. But, in coming back to this country, they bring many empty petroleum casks, and the Stassfurt fertilizers have been found to be well adapted to serve as ballast to keep such barrel-laden ships steady. The owners of the vessels care only for the weight of the fertilizers; and, since they have usually but little command of capital, they naturally prefer to take those classes of salts which will give them the largest amount of dead weight at the least cost.

V. A sample of dark gray " prussiate residue," from prussiate of potash works at New Bedford, Mass., obtained from W. H. Chessman, of Boston, dealer in potashes. This substance was readily and completely soluble in water. It contained, among other things, —

Moisture	1.71 — 2.13%
Silicic acid	1.09
Sulphuric acid	1.01
Phosphoric acid	0.47
Real potash (K_2O)	43.14

Beside the constituents enumerated above, the sample contained carbonic acid, traces of iron and alumina, a good deal of sodium, and a small proportion of an alkaline sulphide. A small quantity of sulphuretted hydrogen was evolved on adding an acid to the substance or

to its aqueous solution. On being tested as to its alkalinity, it appeared that the substance neutralized as much standard acid as would be equivalent to 51.25 pounds of pure dry carbonate of potash for every hundred pounds of the material. In the spring of 1874, this substance was offered at retail in Boston for three cents per pound, a price that was manifestly too high, in so far as the real potash was concerned, since it made the pound of that ingredient come to nearly seven cents at a time when it could be bought in Boston at 5½ cents in the form of muriate of potash, as has just been shown.

The proportion of potash in the prussiate residues is naturally subject to considerable variation. Thus a sample offered in the spring of 1874, by a New York dealer in fertilizers, Mr. George E. White, of 160 Front Street, contained 54% of real potash, according to the certificate of a chemist of that city; and, since the article was sold at 2¾ cents per pound, it appears that the pound of real potash would have cost in this form a trifle more than five cents. That is to say, but little more than it would have cost in the form of muriate of potash, for the price of the 80% muriate at that time in New York was 2½ cents per pound, which is equal to five cents per pound for real potash.

As a matter of course, rather more care would be required in using a substance such as this, which contains a soluble sulphide, than would be needed for the successful application of the better kinds of Stassfurt fertilizers. The farmer would have to be upon his guard lest the poisonous ingredient should actually harm his crop. The prussiate residues are well adapted, however, for composting peat, and, at least as regards the sample examined in this laboratory, could do no harm when applied in moderate doses to plough-land some days before any seeds were to be sown. The small amount of sulphide which the fertilizer contains would be quickly destroyed in the earth, through oxidation and by the action of carbonic acid from the air and the soil. It is possible that in some cases the sulphide of the prussiate residue might be made to serve a useful purpose in destroying weeds, insects, or fungi; and it might sometimes happen that on this account the farmer would be justified in giving the preference to the prussiate residue over another fertilizer equally rich in potash. This remark would probably apply with greater force to a certain by-product which occurs in the manufacture of the purest cyanide of potassium for electroplaters' use than to the prussiate residues above described. These

cyanide residues are said to be bought and sold in considerable quantities in New York at cheap rates. They are obtained from the mother liquors whence pure cyanide of potassium has been separated by crystallization. They are said to contain a high percentage of potash (more than 50%), and to be used by the makers of fertilizers as a means of putting potash into their wares. Such residues would probably almost always contain more or less cyanide of potassium, which, as was just suggested, might sometimes be used with advantage for destroying noxious insects, or perhaps plants. Once mixed with the soil, it would soon lose any cyanide of potassium that may have been contained in it, since that compound would be decomposed, and made harmless by the action of carbonic acid. As regards the practice of mixing the cyanide residues with other commercial fertilizers, for the sake of introducing a certain amount of potash, the practice would seem to be safe enough in so far as concerns the superphosphates; for the soluble phosphoric acid of a true superphosphate would quickly decompose any cyanide of potassium with which it came in contact, as it would the alkaline sulphide in a prussiate residue. But when mixed with most kinds of commercial manures, other than the true superphosphates, the cyanide residues would undergo no such purification: they would be simply concealed in the mixture, and from the very fact of their concealment would be more likely to do harm than when used by themselves. This remark illustrates one general objection to the custom of buying mixed manures, which seems to be gaining ground in this vicinity. There are many reasons why the farmer should as a rule buy his potassic, phosphatic, and nitrogenous fertilizers separately, and judge for himself as to the proportion in which each should be used upon any given farm or field; and not least among these reasons is the security which is gained of knowing the character of each of the materials with which he means to deal. There is little risk in applying any manure whose attributes are clearly understood, and of the substances now in question it may be said that the peculiarities of both are palpable. It would be easy to recognize either the prussiate residue or that from the cyanide so long as the residues were kept by themselves; but when mixed with other fertilizers it might be hard to detect them, and it would usually be very difficult to judge of the amount of either of them that the mixture contained. It may be remarked in this connection that much harm has actually been done in

Europe through the practice which prevails there to a certain extent of mixing sulphocyanide of ammonium (or sulphate of ammonia that is contaminated with the sulphocyanide) with phosphatic manures. The sulphocyanide is obtained in considerable quantities at very small cost, as an incidental product in one of the processes ordinarily employed for purifying illuminating gas. It is thrown upon the market at a low price, and has doubtless been a good deal used by careless and unscrupulous manufacturers of the so-called ammoniated superphosphates. An advertisement such as the following, copied from the "London Chemical News" of Nov. 20, 1874,—"Sulphocyanide Ammonium: About 20 tons for sale, containing nitrogen equal to 34 per cent ammonia,"—would naturally attract the attention of dealers in manures, and would be likely to tempt the unprincipled. It should again be said, however, that the sulphocyanide, though inadmissible as an ingredient of mixed manures, may eventually prove to be of real value to the farmer as an agent for destroying insects, fungi, and weeds.

VI. *A sample of saltpetre waste* obtained from a manufacturer of gunpowder in the winter of 1874, by Henry Saltonstall, Esq. Two analyses of the sample gave the following results:—

	A.	B.	Mean of the Two Analyses.
Moisture	4.94%	——	——
Potash (K_2O)	26.61	26.70	26.65
Sulphuric acid	1.88	1.37	1.63
Nitric acid (N_2O_5)	7.28	7.59	7.44
[Or, nitrogen	1.89	1.97	1.93]

The sample represented thirty tons of the waste which had accumulated at the powder mill, and the lot was offered for sale at 1½ cents per pound, delivered in Boston. At the time when the sample was procured, nitrogen in the form of nitrate of soda cost rather more than 24 cents (currency) per pound in Boston; and potash in the form of muriate of potash was worth 5½ cents per pound, as was stated on page 379. Hence the saltpetre waste could be credited with 46 cents per hundred pounds on account of the nitrogen contained in it, and with $1.47 on account of the potash. It was intrinsically worth nearly two cents per pound, although offered for sale at a cent and a half.

There are, doubtless, a number of localities in this country, in the vicinity of powder mills, where small quantities of saltpetre

waste may be obtained occasionally at a low price, for the waste is good for nothing except to be used as manure. But, from the nature of the case, the saltpetre waste is liable to vary greatly in quality; and, since its value depends almost wholly upon the nitric acid and the potash that are contained in it, the farmer should be careful to have the proportion of these ingredients determined by the analysis of a fair sample of the material each and every time that he wishes to purchase any of it. When the quantity of waste to be disposed of is as large as the lot from which the foregoing sample was drawn, the cost of an analysis would be small in comparison with the value of the material, and would hardly be felt at all if several farmers were to combine to buy the whole of the waste with the view of dividing it and the costs of procuring it, among them. As an example of the varying character of saltpetre waste an analysis reported by Professor Johnson,* of New Haven, in 1868, may be cited. Johnson's sample was found to contain 9.63% of potash and 2.90% of nitric acid [or nitrogen 1.04%] and moisture 11.52%, while its price was $35 per ton.

It is of interest to note that the proportions of the saline constituents in Johnson's sample were unlike those of the sample analyzed in the Bussey laboratory. Thus while Johnson could report as a probable arrangement of the bases and acids the statement given below under C; the small amount of sulphuric acid in my sample precluded such an arrangement, and suggests the statement (taken from analysis A) which is given under D. In a word, Johnson's sample contained a large proportion of sulphates, and my sample contained a large amount of chlorides.

	C.	D.
Sulphate of potash	11.39%	4.10%
Sulphate of soda	22.52	——
Chloride of sodium	38.75	about 45.00
Nitrate of potash	7.45	13.62
Chloride of potassium	——	28.63
Moisture	11.52	4.94

It is not unlikely that the saltpetre waste, D, resulted from a process of manufacture different from that used in the case of C. Perhaps the latter came from the simple recrystallization of East Indian saltpetre; while D may have been formed in some one of the processes by which nitrate of soda is converted to nitrate of potash by treatment with a

* Report Connecticut Board of Agriculture, 1868, p. 217.

potash salt. It is noteworthy in this connection that the price of saltpetre itself (nitrate of potash) has undergone a great reduction of late years, thanks to the production of enormous quantities of cheap chloride of potassium at Stassfurt, and to the facility with which saltpetre may be made from that salt and the nitrate of soda from Peru. Thus, at the present time (November, 1875), crude saltpetre is quoted at $5\frac{7}{8}$ to $6\frac{1}{2}$ cents gold, or about seven cents, currency, per pound in Boston; and, although this price is still too high to admit of the saltpetre itself being used as a manure, it is nevertheless evident that, as prices now go, the saltpetre waste of the gunpowder makers will henceforth probably be more valuable as a fertilizer than it was in the days when saltpetre was comparatively speaking a costly salt. With saltpetre as cheap as it now is, a refiner operating on the small scale could hardly afford to be as careful to save saltpetre in his processes of crystallization as he once was. He would be justified in leaving a considerably larger proportion of potash and of nitric acid in the "waste" nowadays than formerly.

That saltpetre itself, at the price just stated, cannot economically be used as manure will appear from the following considerations. If we admit that the crude salt contains 90% of pure nitrate of potash, as it often very nearly does, then every hundred pounds of the crude article would represent 42 lbs. of real potash and nearly $12\frac{1}{2}$ lbs. of nitrogen. But real potash can be got at five cents per pound at the present time in the form of muriate of potash, and the nitrogen in nitrate of soda costs about 20 cents* per pound, if we allow 15% of nitrogen in the crude nitrate of soda, which can be bought at present for a trifle more than three cents per pound currency. Hence it appears that the intrinsic value to the farmer of a hundred pounds of the crude saltpetre is only \$4.60, while it would cost him \$7.00.

The beneficial action both of saltpetre-waste and of saltpetre itself (nitrate of potash) on soils in this vicinity has been well illustrated by

* While nitrogen in the form of nitrate of soda can be obtained at so cheap a rate, the farmer should be upon his guard not to pay a disproportionate price for nitrogen that he may wish to buy in some other form. While the price of nitrate of soda is thus reduced, the price of various other nitrogenous manures, such as meat-dust and the dried refuse of slaughter-houses, should by good rights fall also. It is to be observed that the calculations of the values of certain nitrogenous manures given on pages 17, 18 of this Bulletin were based upon a much higher value for the pound of nitrogen than can be admitted at the present time.

the experiments cited by Mr. Colman, in his "Fourth Report of the Agriculture of Massachusetts," Boston, 1841, pp. 334–339.

VI. A sample of the so-called "Slurry" of the flint-glass makers, obtained from the works of the New England Glass Company at East Cambridge in the spring of 1875.

In order to avoid all risk of impurity in the carbonate of potash used for making the better kinds of glass, it is customary in this country to purify pearlash at the glass works. In the process of purification the less soluble part of the pearlash is excluded as a waste product, which consists of sulphate of potash for the most part, and which may be obtained at glass works, as the so-called slurry. This slurry is a fine white powder, or rather salve, for the powder being saturated with mother-liquor that contains carbonate of potash is thereby made moist, slimy, and coherent. The slurry is of interest to the farmer, since it offers him one source of high-grade sulphate of potash. It has in fact long been used as such by the manufacturers of alum. That it is a powerful manure of special value upon our poor New England soils was shown long ago by the field experiments of Mr. Deming Jarves and others, at Sandwich, reported by Mr. Colman, in his "Fourth Report of the Agriculture of Massachusetts," Boston, 1841, pp. 344, 345. Mr. Jarves insists upon the importance of mixing the material thoroughly with earth before applying it to the land, since from its unctuous character it is apt to lie in lumps, and do more harm than good. He used ten horse-cart loads of loam for each barrel of the slurry. The sample in question, which was actually wet and undrained, contained, —

Moisture	18.41%
Silicic acid	.27
Sulphuric acid	30.55
Real potash (K_2O)	43.59
Phosphoric acid	a trace
Or, in terms of saline combinations: —	
Sulphate of potash	66.53%
Carbonate of potash	11.16

The sample contained some chlorine and a little lime and alumina, but no soda, or as good as none; on testing it with a standard acid there was found as much alkali as would amount to 12.82%, in terms of pure dry carbonate of potash.

VII. *A sample of ashes from the husk of cotton seed*, obtained in the spring of 1872 from W. H. Chessman, dealer in potashes, of Boston. The ashes in question had been brought from the South, as an experiment. They were said to have come from a manufactory where the husks of cotton seed were used as fuel under a steam boiler. It was believed that in case there were a demand for such ashes they could be procured cheaply enough to admit of their being sold at that time in Boston for $25 per ton. Analyses of two separate portions of the sample gave the following results: —

	A.	B.
Phosphoric acid	9.10%	9.97
Potash (K_2O)	——	14.11
Sand and charcoal insoluble in acids . . .	21.41	15.63

In a lye obtained by leaching these ashes with water there was found as much alkali as would amount to 12.29% of the ashes, on the assumption that the whole of the alkali was in the form of pure dry carbonate of potash.

Such ashes would be worth more than $25 per ton in Boston at the present time, even if the worth of the phosphoric acid be estimated as low as six cents per pound, and no account be taken of the "alkali-power." But in estimating the value of ashes it is unfair to rely solely upon the amounts of potash and phosphoric acid that are contained in them, for the alkalinity of the ashes is an important consideration even from the farmer's point of view. The fact that wood-ashes can act as an alkali, that is to say can bring to pass certain chemical changes and decompositions such as the alkalies produce, but which neutral potash salts, like the sulphate and the muriate, taken by themselves, cannot effect, is a power which the farmer should neither lose sight of nor neglect.

It has long been known that wood-ashes are particularly well adapted for composting peat and other organic matters, and there can be no question that the efficiency of the ashes in this regard depends upon their alkalinity, especially since Angus Smith * has shown that if a soil rich in organic matter be made alkaline, as well as moist and warm, putrefactive decomposition may shortly set in. When a certain proportion † of wood-ashes, or of lye obtained by leaching wood-ashes, or

* Johnson's "How Crops Feed," New York, 1870, p. 266.

† One common rule among practical men is 12 bushels of ashes to 100 bushels of peat.

For the action of alkalies upon peat and loam, see further pages 280, 281 of this Bulletin.

of a solution of one of the cheap kinds of commercial potashes that are prepared from ashes, is mixed with peat, loam, sods, weeds, leaves, straw, twigs, or almost any kind of organic matter, the latter quickly undergo change, provided the mixture is duly moistened and kept in a moderately warm place. By the changes thus induced, peat and many other substances which, considered as fertilizing agents, are comparatively inert and slow of action when in their natural or crude state, and which if left to themselves would resist decay for a long time, are soon converted to more or less powerful manures that are held in high estimation by practical men. Not only is the structure or organization of the peat or leaves or twigs destroyed by the action of the alkali, and by virtue of the fermentation which it induces, but the nitrogenized constituents of the inert organic matters undergo such changes that a good part of them are made immediately available for the use of growing crops. But since the ashes themselves contain a good store of potash and phosphoric acid it follows that a compost properly prepared by means of ashes must be a complete manure, competent to supply plants abundantly with all those kinds of food that are not likely to be met with in every agricultural soil.

There are of course, besides the alkali in wood-ashes, various other agents competent to bring about the fermentations and some of the other changes upon which the production of compost depends. Dung, and urine, fish, flesh, and offal, are all efficient agents, and so are guano, soda ash, lime, and mixtures of lime and salt; but there are few things applicable to this purpose that are at once so powerful, so manageable, and so intrinsically useful as ashes. When used in this way they lose none of their power of feeding plants directly which is due to the potash and the phosphoric acid contained in them. Of course, any risk of harm that might arise from the injudicious application of ashes directly to a field crop, whether in too large quantity or at an inopportune season, would be avoided by composting the ashes, since the same corrosive power that might injure the crop would be expended or annulled in the compost heap. The tendency of ashes to injure seeds and young plants depends on the same cause which makes the ashes specially valuable in the compost heap as a means of destroying the roots and seeds of weeds.

It is well known that the amount of alkali-power in ashes varies considerably in different samples. This fact may be seen on inspecting

the table on pages 207–245 of this Bulletin, where (in column six of the table) are given a number of determinations of the proportion of salts soluble in water, or crude potashes, that have been obtained from the ashes of different kinds of woods by various experimenters. But since the figures given in that table do not usually represent the alkali-power of the ashes precisely, but only give a more or less vague approximation to it, I have myself had the actual alkali-power determined in a number of samples of wood-ashes obtained from household fires here in New England. That is to say, I have determined the power of neutralizing an acid that was possessed by the solutions (lyes) obtained when the ashes were carefully leached with water. The ashes thus examined were the samples that have been described already on page 191 of this Bulletin, and the estimations of alkali-power now under discussion were made at the same time as the determinations given on page 193. The results obtained were as follows: The alkalinity (column 3) being stated in terms of pure dry carbonate of potash (K_2O, CO_2).

No. of the Specimen (as on pp. 191–193).	Source whence the ashes were derived.	Alkali power: — 100 parts of the ashes contained parts of K_2O, CO_2, or its equivalent.	Per cent of salts soluble in water, *i.e.*, crude potashes.
I.	Soapboiler's ashes	7.21 — 8.05	9.40 — 10.80
II.	Ditto	7.86 — 8.24	9.63 — 8.75
III.	Dwelling-house	12.35	19.67
IV.	Ditto	8.65	13.67
V.	Ditto	10.18	14.56
VI.	Ditto	12.36	14.51
VII.	Ditto	12.35	14.15
IX.	Ditto	11.53	14.52
X.	Ditto	10.17	13.95
XI.	Ditto	15.72	16.28
XII.	Ditto	10.81	10.65
XIII.	Ditto	6.53	10.75

In each hundred pounds of the ashes there was found as much alkali as would be equivalent to the number of pounds of carbonate of potash

that are given in the third column of the table. For the sake of contrast, I have given in the fourth column the number of pounds of salts soluble in water, or "crude potashes" that were obtained from each of my samples of ashes. These figures represent the amounts of solid matter that were obtained on evaporating measured quantities of the lyes and igniting the dry residues; they are comparable with most of the figures in column six of the table on pages 207–245.

It has been shown already, on page 387, that the alkali-power of the ashes from husk of cotton seed was found to be 12.29% in terms of pure carbonate of potash; that is to say, about the same as that of several of the best samples of wood-ashes. The alkali-power of the New Bedford prussiate residue was high; namely, 51%. This substance is doubtless well adapted for making compost, as has been already suggested.

It is no very easy matter to determine the precise money value to the farmer of the alkali-power of ashes. In the lack of more definite means of information, and taking, one year with another, perhaps as fair a way as any of arriving at an approximate valuation would be to credit the ashes with the cost of as much soda ash as would represent the alkali in the ashes. Thus, at the present time (November, 1875), soda ash containing 80% of pure carbonate of soda is quoted at three cents (currency) per pound in Boston; and, in order to get as much alkali in this form as would be equivalent to the 10 pounds of carbonate of potash which may be assumed to be contained on the average in 100 pounds of wood-ashes, $9\frac{1}{2}$ pounds of the soda ash would be needed. Hence the sum of 29 cents, which this amount of soda ash would cost, may be taken as the alkali value of the 100 pounds of wood-ashes; and each pound of the carbonate of potash in the ashes may be estimated to be worth $\$0.29 \div 10 = \$0.029$; that is to say, nearly three cents, on account of its alkalinity alone. But since house ashes are held to weigh 48 pounds to the bushel, on the average, the alkali-worth of a bushel of ashes, as prices now go, may be said to be about 14 cents. Now, from the averages of the analyses that have been given on page 193, it appears that ashes contain about $8\frac{1}{2}$% of real potash and about 2% of phosphoric acid; and, if we allow five cents per pound for the potash and six cents per pound for the phosphoric acid, there will be 26 cents per bushel to be added to the alkali-worth (14 cents) that was just now given. Whence it appears that

the agricultural value of wood-ashes may be rated at 40 cents per bushel.

Another way of looking at the matter would be to contrast the wood-ashes with our American potashes. At the present time potashes are quoted in the Boston newspapers at five cents per pound. Let us assume, for the sake of the argument, that the average commercial article has an alkali-power equivalent to from 65 to 70% of pure carbonate of potash, account being taken of both the caustic and carbonated potash and the carbonate of soda that the potashes may contain. Let it be admitted furthermore that American potashes contain as much as 60% of real potash (K_2O) if all that which is present in the form of sulphate and chloride be allowed for.* There would be then in a hundred pounds of the potashes three dollars' worth of real potash, — that is to say, as much real potash as would cost the farmer three dollars if he were to buy it in the form of the neutral salt muriate of potash at its present price, — and the cost of the alkali-power of the potashes would be the difference between this sum and the price at which the potashes are actually sold. That is to say, the cost of the hundred pounds of potashes ($5.00), minus the worth of the sixty pounds of real potash contained in them ($3.00), is equal to two dollars, the cost of their alkali-power.

From these data it would appear that ($2.00 ÷ 65 =) $0.031, or ($2.00 ÷ 70 =) $0.029 may be allowed for each pound of the carbonate of potash, on account of alkali-power, accordingly as the potashes are rated as containing 65% or 70% of that substance; a result which is surprisingly like the one just now obtained by the calculation based on the price of soda ash. Such calculations are of course to be regarded as mere rough approximations or suggestions upon which to found an opinion of the real value of ashes; but they go to show that, while the price of 80% muriate of potash is no lower than 2½ cents per pound, American potashes at five cents per pound may be classed as a cheap manure.

It is an interesting question, that needs to be tested by experiment, whether mixtures of the Stassfurt potash salts and quicklime can be employed as advantageously for making compost as wood-ashes, or as

* Compare F. Mayer, "American Journal of Pharmacy," **32.** 132; and Grüneberg, Wagner's "Jahresbericht der chemischen Technologie," **9.** 288.

potashes at their present low price. However that may be, there is little reason to doubt but that the Stassfurt fertilizers admixed with lime would be found to be better fitted for making compost than the common "salt and lime mixture" which has been so much used in New England and in the Southern States. The sulphate of potash in particular, of tolerably high grade, would seem to be much better suited for this purpose than common salt.

As is well known, the salt and lime process consists in slaking quicklime with brine, and mixing the slaked lime with peat or with the other organic matters that are to be composted. One way of proceeding is to dissolve a quantity of common salt in water, and to slake the quicklime with as much of this brine as would bring the lime to the condition of fine powder. The powdery slaked lime is then spread, while still warm, between layers of the peat. The efficiency of the salt and lime mixture doubtless depends, as Professor Johnson has urged in his "Peat and its Uses," New York, 1866, p. 74, upon the unequal rates of diffusion of the chemical substances which either exist originally in the lime and salt mixture, or which may be formed from it under the conditions that obtain in the compost heap. Small quantities of caustic soda and chloride of calcium are doubtless formed under these conditions, and are carried into the moist peat in accordance with the laws that govern the diffusion of liquids. The peat, or a part of it at least, is thus exposed to the powerful action of the soluble alkali soda, and of the carbonate of soda into which the hydrated soda at first formed is soon converted, and on that account the organic matter undergoes a more rapid and complete decomposition than would be brought about by the lime alone. It is plain, however, that the use of salt in this way is merely a clumsy device for adding a small proportion of soluble alkali to a lime compost. The process amounts to no more than adding a little soda ash to the lime. But as Graham * has been at pains to show, in his researches on the diffusion of liquids, the potash salts, as a rule, exceed those of soda in diffusibility. Hydrate of potash in particular is an eminently diffusive substance, having double the diffusibility of sulphate of potash. Graham found in fact that sulphate of potash was decomposed to a marked extent by lime

* "Philosophical Transactions of the Royal Society," London, 1850, **140.** 21; 1851, pp. 484, 494. "Quarterly Journal Chemical Society of London," 1851, **3.** pp.61–67.

water, — with diffusion of hydrate of potash, — under conditions in which neither chloride of potassium nor chloride of sodium was sensibly decomposed by the lime water. He found, furthermore, that sulphate of lime was only one-fourth part as diffusive as hydrate of potash.

Experience alone can decide as to the availability of the potash salts for the purpose now in question. It can be said only that the laboratory experiments of Graham go to show that as regards the subject of diffusibility, chloride of potassium (muriate of potash) is a somewhat better material to mix with lime than chloride of sodium (common salt); and that sulphate of potash is decidedly better than muriate of potash. But since neither common salt itself nor the products of its decomposition by lime are of any direct use as plant food, while both the Stassfurt salts are powerful manures, it would manifestly be better to employ one of the latter in conjunction with the lime, even if the diffusibility of the products of the decomposition of the potash salts were less than it really is. Since sulphate of potash is less readily soluble in water than common salt, it might not be convenient to slake the quicklime with a solution of it; but it is to be remembered that the ordinary process of slaking the lime with brine is in no wise essential: the decompositions due to diffusion would doubtless occur if the lime were slaked with water and the salt were added afterwards. Hence the dry sulphate of potash might be scattered upon the slaked lime after the latter had been strewn upon the peat, or the sulphate of potash might be dissolved in boiling water, and the hot solution thrown upon the layers of powdery slaked lime as they lie upon the peat.

A practical example of the efficiency of the mixture of lime and sulphate of potash has been cited by Peters,* who found that such a mixture did better than a mixture of lime and wood ashes for decomposing coarse bones. The same chemist † has recommended a mixture of Stassfurt salt and lime for composting moor-earth.

It is an interesting fact to be remembered with regard to the Stassfurt salts, that it is not by their direct importation alone that they will make available for American farmers the potash of which so many of

* Hoffmann's "Jahresbericht der Agrikultur-Chemie," 1866, **9**. 237.

† Löbe's "Landwirthschaftliche Fortschritt," **2**. 29.

our soils stand in urgent need. These German fertilizers will really set free here in America, for agricultural use, a large amount of wood-ashes that have hitherto been used for making potashes which were consumed in the arts. Ever since the first settlement of the country American potashes have been an important article of exportation. But it is plain that this exportation must greatly diminish, even if it does not altogether cease, in view of the inexhaustible supply of potash salts that are readily obtainable at the German mines, — not only the mines at Stassfurt, but those in other localities that have been discovered more recently. Both potashes and pearlashes can be readily and cheaply prepared from the Stassfurt salts. They are so prepared already in large quantities, and this fact is doubtless one main reason why the price of American potashes is now so low in the home market. There is little doubt but that when the use of the German potashes has once become tolerably well established the demand for them will rapidly increase, to the disadvantage of the American article. Any manufactured product which, like the German potashes, is made from materials which, besides being abundant and cheap, are themselves pure,* or of definite and constant composition, can naturally be made of more uniform composition, and in the long run cheaper and better than the potash obtained from wood-ashes, which is a material notoriously liable to wide variations in composition, particularly as regards the proportion of what may be called its saline impurities.

As a matter of course, it will take some time to oust American potashes from the markets of the world. The process of depression will be intermittent and gradual, and the price of our potashes will doubtless be subject to considerable fluctuations for some years to come. As regards pearlash, indeed, which is, comparatively speaking, a pure chemical substance, the contest will be short. But there are scores of practical receipts, formulæ, and processes in the arts in which the operator is directed to use American potashes, and in which long experience has led him to believe that the use of American potashes is essential to success. It is not easy to eradicate prejudices such as these, and it ought not to be. But there can be no doubt that they must finally give way to more intelligent practices. The history of

* Specially high grades of chloride of potassium, containing respectively 95 @ 96% and 98 @ 99% of the pure salt, are prepared at Stassfurt expressly for the manufacture of potashes, and of chlorate and chromate of potash.

the chemical arts is filled with examples almost precisely similar to this one. No doubt but that one step in the process of introducing the German potashes will be the fabrication from them of imitations of the American potashes in which all the impurities and peculiarities of the latter will be found as well as the outward appearances. However this may be, it remains clear that wood-ashes are likely to become more generally available for American farmers than they have ever been before. Hence the importance of considering carefully the intrinsic worth of wood-ashes and the ways and means of procuring them.

On inquiry, I learn from a prominent Boston dealer in potashes, that nowhere in this country is wood burned nowadays by potash makers for the sake of its ashes. It is only where ashes can be cheaply collected by wagons driven from house to house that potashes are still made. At present potashes come chiefly from the Western States and from Canada; from Milwaukee in particular, and from as far away as St. Paul. A small quantity still comes from Vermont, and some from the State of New York. In Maine, also, potashes are made at Bangor, the wood-ashes being collected not only from house to house in the vicinity of that city, but brought there in car loads by railway. Soap-boilers are almost everywhere the makers of potashes at the present time. Wherever a soap-boiler is established he collects the wood-ashes of his neighborhood and leaches them. In so far as there is a local demand for soft soap he employs the potassic lyes for making such soap, and the remainder of the lye he boils down and disposes of in the form of potashes.

When the price of American potashes shall have fallen to the point at which the manufacture of them ceases to be profitable, or even before that point is reached, it will often be worth the farmer's while to inquire of the soap-boilers and the railway companies whether wood-ashes cannot be brought to him at a price which he will be willing to pay. That such transportation is perfectly practicable is shown by the fact that damp leached ashes of comparatively little real worth have for many years been a regular article of transportation from the wooded regions of northern New York and the Canadas to Connecticut, Long Island, and the New England seaboard.* I am informed that a farmer of Plymouth county in this State, who, in the autumn of

* As described by Professor Johnson, in his article on the value of leached ashes in "Report Connecticut Board of Agriculture," 1872–73, p. 417.

1872, procured a considerable quantity of ashes from a town in Maine, paid \$1.60 per ton for moving the ashes thirty miles by railroad to Portland, and \$2.00 per ton for bringing them from Portland to Boston, more than one hundred miles by steamboat. The cost of transferring the ashes from rail car to steamboat at Portland was \$0.25 per ton. That is to say, the total cost per ton for transporting the ashes to Boston was \$3.85, or nine cents per bushel, if we allow forty-two bushels of ashes to the ton. It is plain from what has been stated on page 390, as to the real value of ashes, that the farmers of this vicinity would be justified in paying a considerable sum per bushel for ashes in Maine, so long as the costs of transportation are no greater than this.

In buying ashes, it would usually be easy to guard against the risk of adulteration by determining the specific gravity of the lye obtained from the sample that may happen to be under consideration.* To this end put a definite weight, say $\frac{1}{4}$ pound, of the ashes to be tested in a bottle, together with a pint and a half of rain water, and shake the mixture at intervals during several hours. Then pour off the tolerably clear lye, test it with a delicate hydrometer, and compare the result with other results that have been obtained by testing in the same way several standard samples of ashes. Since the substances with which wood-ashes are liable to be adulterated; viz., coal-ashes, loam, and sand, contain only a small proportion of matters that are soluble in water, the specific gravity of lyes obtained by leaching ashes thus adulterated would necessarily be proportionately low. In order to be convinced of this fact, and to perceive its true significance, it would be well for the experimenter to make and test a series of mixtures of good wood-ashes and sand, or coal-ashes, in varying proportions; for example, one, two, and three ounces of the wood-ashes, with enough sand or coal-ashes in each instance to make up the quarter-pound needed for the test. Of course, the test applies with its full force only to dry ashes, that is to say to ashes that have never been wet, for it might be possible, though hardly practicable, economically speaking, to drench coal-ashes or leached ashes with refuse saline lyes of one kind or another that would act upon the hydrometer like potash lye.

This specific-gravity test, simple though it be, is really one of con-

* As has been recently suggested by Nessler. See Biedermann's "Central-Blatt für Agrikultur Chemie," 1874, 6. 420.

siderable merit. In certain cases it may be decidedly better than the ordinary alkalimetric test employed by chemists, as will appear from the following statement. A quantity of ashes that had been formed at a manufactory by burning chips of leached dyewood, at a very high temperature, in a furnace of peculiar construction, on being examined in the Bussey laboratory were found to consist of carbonate of lime for the most part, though they contained enough quick-lime to amount to 5.4% of the ashes. Now, although the amount of potash (K_2O) contained in these ashes was less than half of one per cent, the clear lye obtained from them when subjected to the usual alkalimetric test neutralized as much standard acid as would indicate that the ashes contained 13.31% of pure carbonate of potash. The lye was in fact a well-nigh saturated solution of caustic lime; and as the equivalent weight of quick-lime (28) is to that of carbonate of potash (69.11) so is 5.4% (the per cent of caustic lime actually found) to 13.31%; *i.e.*, the supposititious percentage of carbonate of potash.

By mixing a small proportion of quick-lime, or even of spent lime from gasworks, with coal-ashes, it would be an easy matter, to obtain a dry product looking a good deal like wood-ashes, that would yield a lye as alkaline as that obtained from the strongly ignited ashes of the leached dyewood that have just been cited. Hence it is well to inquire how much influence the solution of lime would have upon the specific-gravity test. To determine this point I have caused to be taken the specific gravities of the solutions enumerated in the following list: —

Name of the solution:	Specific gravity (at 15° C.).
Lime water	1.0023
Lime water saturated with sulphate of lime	1.0036
"Lye" obtained from $\frac{1}{4}$ lb. of ashes of anthracite and $1\frac{1}{2}$ pints of rain water	1.0004
Lye obtained from $\frac{1}{4}$ lb. of wood ashes (No. VII.) and $1\frac{1}{2}$ pints of rain water	1.0126

Whence it appears that wood-ashes could readily be distinguished from coal-ashes that had been mixed with lime, although, as has just been shown, the usual alkalimetric test might be incompetent to distinguish between them. It is true of course that if oxalic acid were used as the standard acid, in testing such ashes, the formation of insoluble oxalate of lime in the liquid would be almost sure to attract the attention of the analyst, and put him upon his guard. But there would be no such warning if the other common acids were used.

No. 20. — *On the Occurrence of Ammonia in Anthracite.* By F. H. Storer, Professor of Agricultural Chemistry.

From examinations of several samples of the coal which have been made in the Bussey laboratory, it appears that some soluble compound of ammonium is often contained in Pennsylvania anthracite, such as is used for fuel in this vicinity. Thus: —

I. 932 grammes of small fragments of white-ash anthracite ("slack"), taken from a bin in which coarse furnace-coal is kept at the Bussey Institution, were percolated with a litre and a half of rain-water; the percolate was distilled, and the distillate tested, with the utmost care, with Nessler's reagent;* 0.021 gramme of ammonia (NH_3) was found in the 1500 cc. of percolate. But, since the rain-water itself contained 0.0005 gramme of ammonia to the litre, the amount of ammonia obtained from the coal was really 0.02025 gramme, or 0.00217 per cent of the weight of the coal.

II. 320 grammes of fine coal from a bin at the Bussey Institution, in which a not very coarse white-ash stove-coal is kept, percolated with two litres of rain-water and tested as before, gave 0.0036 gramme of ammonia, or corrected for the amount contained in the rain-water, 0.0026 gramme, — that is to say, 0.0008 % of the weight of the coal.

III. 530 grammes of coal-dust from a dwelling-house in Boston, percolated with two litres of water free from ammonia, and tested as before, gave 0.03 gramme of ammonia, or 0.00566 % of the weight of the coal.

IV. 560 grammes of coal-dust, taken at another time from the same bin as No. II, and percolated with two and a half litres of water free from ammonia, gave on mere distillation 0.0025 gramme of ammonia, or 0.00045 % of the weight of the coal.

V. 600 grammes of coal-dust, taken at still another time from the same bin as Nos. II and IV, were percolated with rain-water, and the percolate was distilled as before; but no ammonia could be detected in the distillate, not even the amount that was known to be contained in the rain-water that was used. But, on transferring the residual liquor to a flask charged with milk of lime that had just been boiled to expel any trace of ammonia, and again distilling, an abundance of ammonia (nearly 0.003 gramme) came forward, — that is to say, about 0.0005 %.

Several small bits of lime-mortar were noticed in this sample of coal-dust; and it was observed, furthermore, that the percolate, though colorless at first, soon became yellow and cloudy, and that, after a while, flocks of some compound of iron were deposited from it. The inference is

* See Wanklyn's "Water Analysis," London, 1874.

plain, that the coal contained some soluble salt of iron, and that the ammonia which the lime set free had been previously held back by the acid of the iron salt. It must, indeed, often happen that anthracite, and especially the dust of anthracite, is so highly charged with sulphate of iron that no ammonia can be expelled from the coal by mere boiling with water. But, on boiling with milk of lime, with the proper precautions, the ammonia in the coal is readily made manifest.

VI. Several lumps of the stove-coal from the bin whence Nos. II, IV, and V were taken, having been ground to powder in a drug-mill, 10 grammes of the powder were put in a flask with some water free from ammonia, and distilled until no more ammonia came forward; 0.00002 gramme of ammonia was found in the distillate, — that is to say, 0.0002 % of the coal. No additional ammonia was obtained in this case on boiling with milk of lime. But 10 grammes of the powdered coal, boiled with alkaline permanganate of potash, gave 0.000035 gramme of ammonia.

VII. 20 grammes of coal-dust from a bin in my own dwelling-house, on being boiled with pure water, gave 0.00031 gramme of ammonia, or 0.0015 % of the weight of the coal. An attempt to boil the residual liquor with milk of lime failed through the foaming-over of the liquid.

VIII. Selected, clean lumps of furnace-coal from the bin No. I were washed with water free from ammonia, and reduced to a coarse powder: 100 grammes of the powder, distilled with pure water in a flask, gave 0.00011 gramme of ammonia; and as much more was obtained on distilling the residual mixture with milk of lime. The evolution of the ammonia from the mixture of lime and coal was very slow, and was not, in fact, completely finished when the experiment was brought to a close. The total percentage of ammonia found in this case was 0.00022.

IX. 550 grammes of powdered lump-coal from bin No. I, percolated with three litres of pure water, gave 0.0018 gramme of ammonia, or 0.000327 %; and no additional ammonia was given off on boiling with milk of lime.

X. A hard, glassy lump of coal, very compact and difficult to break, taken from bin No. I, was reduced to powder, and 10 grammes of the powder were distilled with pure water; 0.00004 gramme of ammonia was obtained, and an additional faint trace came over on boiling the residue with milk of lime. The per cent of ammonia in this case was 0.0004.

10 grammes of fine powder from this hard lump of coal, on being boiled with an alkaline solution of permanganate of potash, that had been carefully boiled to expel ammonia, yielded 0.00008 gramme of ammonia.

XI. A lump of coal that was somewhat rusty upon its surface, taken from bin No. I, was reduced to powder, and 20 grammes of the powder were distilled with pure water; 0.000035 gramme of ammonia was obtained, or 0.000175 %. No additional ammonia was obtained on boiling with milk of lime.

XII. Several clean lumps taken from a new supply of furnace-coal, at the Bussey Institution, were ground to a moderately fine powder, and 20 grammes of the powder were boiled with milk of lime; 0.00004 gramme of ammonia was obtained, or 0.0002 %.

XIII. A quantity of small fragments of coal ("slack"), from the heap whence No. XII was taken, was sifted through very fine sieves, and 20 grammes of the dust were boiled with milk of lime. The first 250 cc. of distillate contained 0.0005 gramme of ammonia. On further distillation, ammonia continued to come off slowly and constantly; 0.00005 gramme ammonia was found in every fifty cubic centimetres of the distillate, until six such portions had been collected. But the next fifty cc. portion of distillate contained much less ammonia (0.00002 gramme), and the process was then interrupted. All told, there was found in this experiment 0.00082 gramme of ammonia, or 0.0041 %.

On boiling 20 grammes of this coal-dust with alkaline permanganate of potash and with milk of lime, an amount of ammonia was obtained that appeared to be much larger than the quantity just stated, but the precise amount was not determined.

20 grammes of the same sample of coal were shaken together with 500 cc. of pure water, at intervals during two days; and 50 cc. of the clear, supernatant liquid were then tested for ammonia by boiling with milk of lime. There was found 0.00001 gramme, or 0.0005 % of the coal.

XIV. Several large, clean lumps of furnace-coal, taken from the same heap as No. XI, after other loads of fresh coal had been mixed with it, were broken up, and a fair sample of the fragments was powdered; 20 grammes of the powder boiled with milk of lime gave 0.00011 gramme of ammonia, or 0.00055 %.

It is to be observed that the coal whence samples Nos. XI to XIV were taken differed from that of the other samples in that it had been mined a year later. It was examined, moreover, a month or two after it had been mined, instead of six or eight months, as in the other instances.

Some idea of the significance of the figures above recorded may be gained by contrasting the amounts of ammonia in anthracite with the amounts of ammonia that have been found in soils. Thus, while it appears, from the foregoing experiments, that 100 grammes of anthracite ordinarily contain from 0.0002 to 0.0008 or even 0.00566 gramme of ammonia, the experiments of Knop and Wolf,* made upon five different kinds of soils, show no more than from 0.00012 to 0.00087 gramme of ammonia for 100 grammes of anhydrous earth.

* Knop's "Lehrbuch der Agricultur-Chemie," Leipzig, 1868, 2. 86.

The results obtained from the anthracites and from the soils are shown in detail in the following tables.

Recapitulation of the Experiments on Anthracite.

No. of the Experiment.	Ammonia, per cent.
I.	0.00217
II.	0.00080
III.	0.00566
IV.	0.00045
V.	0.00050
VI.	0.00020
VII.	0.00150
VIII.	0.00022
IX.	0.00033
X.	0.00040
XI.	0.00018
XII.	0.00020
XIII.	0.00410
XIV.	0.00055

Knop and Wolf's Experiments on Soils.

Kind of Soil.	Ammonia, per cent in dry soil.
Very poor, light, sandy soil	0.00077
Soil rich in humus from a beech wood	0.00087
Sandy loam from hard-wood forest	0.00012
Mould from forest on bank of river Elster	0.00080
Poor, red, sandy loam from a ploughed field	0.00017
Average	0.000546

The experiments recorded in this article were undertaken, in the first place, for the purpose of finding the source of the nitrogen in a certain sample of anthracite ashes, which were found to be capable of supplying plants, in some way, with a small amount of nitrogenous food, as has been fully explained on page 62 of this Bulletin. Since the ashes in question were known to contain many fragments of unburnt anthracite which had fallen through the grate-bars of the shallow furnace whence they came, it was thought that possibly some part of the inert nitrogen proper to the coal might have been converted to a nitrate by the action of air and moisture upon these unburnt fragments in the pots where the plants were grown. But, on proceeding to test this idea by exposing washed fragments of anthracite to the air, so much ammonia was at once detected in the first washings from the coal, that the proposed experiment was abandoned in favor of the tests which have been recorded above.

The proved presence of ammonia in the anthracite fragments explains, of course, where the plants of page 62 got their small supply of nitrogen; and on testing anew, in the light of the experience that has just been related, some ashes similar to those used in the experiments of page 62, an appreciable amount of ammonia was found in them, especially in a sample that contained a large proportion of the unburnt fragments of anthracite.

The question naturally presents itself whether the occurrence of ammonia in anthracite may not be connected in some way with the pyrites that so often occur in the coal, or perhaps be due to the presence of ferrous sulphate that has been formed through oxidation of the pyrites. This idea is in harmony with the action of ferrous sulphate noticed above, under experiment No. V, and with the fact that many lignites and alum shales contain not only very considerable quantities of sulphate of iron, but often a good deal of sulphate of ammonia also.* The fact noticed in this laboratory,† that commercial copperas often contains appreciable traces of ammonia, likewise obtrudes itself in this connection. It is not unlikely that one or both of these substances may take part in the reactions by which ammonia is formed upon coal; but I am, nevertheless, inclined to believe that their influence is a subordinate one in the present instance, and that the ammonia is really formed through the decomposition or decay of the nitrogenous matter of the coal, perhaps in the same way that the ammonia which is found in the soil may have been formed from the decay of nitrogenous organic matters. Indeed, there is little reason to doubt but that ammonia may be formed during the slow oxidation of organic substances containing nitrogen that are exposed to the air. It is well known, for example, that ammonia is formed from such matters by the action of ozone,‡ and of other powerful oxidizing agents, such as permanganate of potash, and the like. Ammonia, as well as nitric acid, — that is to say, nitrate of ammonia, — is often found as the result of the oxidation of nitrogenous matters in contact with moist earth; and in the familiar experiment of Stenhouse, where flesh is covered with bone charcoal, a faint odor of ammonia is almost always perceptible as a result of the process of oxidation.

Although several of the foregoing samples of anthracite were carefully tested for nitrites and nitrates, neither of these compounds were detected. These tests for nitrogen oxides were applied in several ways; namely, by adding iodo-zinc starch paste to acidulated percolates from the coal, both before and after the liquids had been boiled for a short time with amalgamated zinc, or had been left standing upon amalgamated zinc for a number of hours at the ordinary temperature;

* See Heiden's "Düngerlehre," 1868, **2.** 356.

† See "American Journal of Science," December, 1875, **10.** 438.

‡ Gorup-Besanez, "Annalen Chemie und Pharmacie," **125.** 209.

by distilling a percolate from the coal with acetic acid, both before and after the action of amalgamated zinc, and testing the distillates with iodo-zinc starch; and by digesting a percolate with metallic aluminum in presence of caustic soda, and distilling the mixture to obtain any ammonia that might have been formed. Negative results were obtained in each instance, although it appeared, from the results of other work that was being done at the same time, that the methods and the reagents employed were excellent and delicate.

I have to thank my assistant, Mr. D. S. Lewis, for his careful attention to the details of this investigation.

No. 21. — *On a Disease of Olive and Orange Trees, occurring in California in the Spring and Summer of* 1875. By W. G. Farlow, Assistant Professor of Botany in Harvard University.

During the past summer, numerous complaints have come from southern California of a fungus which had attacked the olive and orange trees, and which was causing a considerable loss of those two crops. Our attention was first called to the subject by Dr. H. W. Harkness, who, in a letter from San Francisco dated May 11, sent a specimen of the fungus on an orange-leaf from southern California. Of the extent of the ravages of the fungus at that date no information has been received; but, as in a letter from San Diego, dated June 3, Mr. D. Cleveland * wrote that there was no trace of the fungus in that vicinity, we may suppose that the disease first appeared not far from Santa Barbara, where we have definite knowledge of its occurrence, and where great damage was done later in the summer. In a letter from Dr. George Thurber dated September 20, enclosing some specimens of the fungus, is the following from a correspondent in Santa Barbara: "We are troubled with our olive, lemon, and orange trees. A small fungus appears on the leaves, twigs, and branches, at first visible only with a microscope, and of a green color. As it increases in size it turns brown, and then black. The olive is so exhausted that it is unable to fruit. The orange and lemon stand it better, but their fruit is so inferior as to be practically worthless." On the day of the receipt of Dr. Thurber's letter, another was received from Professor Dana, also enclosing specimens from Santa Barbara.

From the general tenor of letters from California, it is evident that, if this is not the first year of the appearance of the disease, it is, at least, the first in which it has attracted general attention; that its effect on the olive and orange crops has not been slightly, but markedly injurious; and that, in its advanced stages, there is present on the leaves and stems a blackish substance, which is universally regarded, by

* We are in receipt of a letter from Mr. Cleveland, dated early in January, 1876, in which he sends specimens of the fungus on orange-leaves, which, he writes, is at that time common at San Diego.

those who have formed any opinion on the subject, as a fungus. We have received, at different times, from California specimens of leaves and stems of orange and olive trees covered with the black growth, and have been able to study the fungus, which presents some points not without interest in a botanical point of view; and, if our conclusions do not point to a direct remedy, it will be conceded, we hope, that we have contributed towards removing some misconceptions as to the nature of the disease. At this distance, remote from all opportunities of observing the disease on living trees, there are, of course, some points in the development of the fungus which we have not been able to study; and our correspondence has not been sufficiently extensive or minute to enable us to give any statistics of the ravages of the disease, to ascertain the climatic or other changes which have preceded or accompanied the breaking out of the epidemic, or to decide whether it is the same form of disease which has been reported to occur in Florida. Our specimens present the disease as it appears when in a somewhat advanced stage, and after the leaves and stems have become so changed as to attract attention.

MYCELIUM. — The leaves of the olives which are affected by the disease are somewhat curled and shrivelled, and are of a browner color than normal leaves which have been gathered but a few weeks. On both surfaces of specimens sent us are black spots of greater or less extent, but in no case is the leaf perfectly black. On the upper surface the black spots are more numerous, more distinct in outline, and harder in substance, than on the lower, where they were more diffuse and of a powdery consistence. The twigs, of which we received only small specimens, are covered with spots which resemble more closely those on the upper than on the lower surface of the leaves. In one specimen the spots are nearly confluent, and the bark is visible in only a few places. After the leaves or stems have been soaked in water for a short time, the black substance can be scraped off without the least trouble, leaving the bark tolerably clean. The black substance, when seen with a magnifying power of four hundred diameters, is found to be composed of the stellate hairs peculiar to the olive, over which is growing a fungus, to the dark color of whose mycelium the spots owe their color. The mycelium is very variable in appearance. As a rule, it is composed of moniliform hyphæ, whose cells are .006 mm. by .008 mm., and in some places almost spherical. The color of the

cell-wall is a dark or purplish brown, and in most of the cells there is a comparatively large-sized oil globule. These hyphæ branch in all directions, and the cells of the branches grow constantly longer, narrower, and paler, although, in all cases, retaining a tinge of brown. The relation of the mycelium to the stellate hairs and outer part of the twigs and leaves is clearly seen in cross sections. The hyphæ run along the surface of the epidermis and of the hairs, which it will be remembered resemble a broadly-opened, short-handled parasol. They are twined closely round the stems of the hairs, so closely, that the fungus cannot be removed without tearing them off. They do not enter into the cells of the olive, and there are no haustoria as in the case of some of the leaf parasites belonging to the *Erysiphei*. Occasionally there are little knob-like projections of the cells which seem to indicate haustoria; but, by the most careful examination which we have been able to make, we have not been able to see that they enter into the cells of the stellate hairs or epidermis and act like haustoria. The surface of the hairs and epidermis, however, seems covered with a sticky substance (of which we shall have more to say hereafter), to which the hyphæ closely adhere. Plate 1, Fig. 2, shows one of the stellate hairs seen from below, with a portion of the mycelium growing upon it.

Various modifications of the mycelium are found principally on that portion growing on the outer part of the stellate hairs exposed to the air. After reaching a certain stage of development, they grow together in such a way that the hyphæ coming together laterally form a sort of membrane, as shown in Plate 1, Fig. 1, *d*. This membrane is composed of only one thickness of cells, but is very uneven as it follows and conforms to the inequalities of the hairs. Its general direction is parallel to the surface of the leaf or stem on which it is found.

Conidia. — The hyphæ, at their free ends, branch in all directions, and bear reproductive bodies of several kinds. The simplest form is that shown in Plate 1, Fig. 3, *d*, where the ordinary cells of the mycelium divide by cross partitions into two parts, which do not respectively grow to the same shape as the mother cell, but remain together two by two, as shown in the figure; the hypha becoming zigzag by the alternate lateral displacement of the pairs of cells, which finally drop off and readily germinate, each cell producing a germinal tube. In other parts of the mycelium, the terminal cell of certain threads di-

vides by means of partitions, parallel to and at right angles to the axis of the filament, until a compound body is formed, which resembles the spores of the so-called genus Macrosporium. These bodies, which can only be described as irregular conglomerations of cells of an oval outline, are produced in great abundance, and average .015 mm. by .025 mm., but are often much larger, though often smaller. They easily drop from their attachments and germinate, each cell being capable of producing a germinal tube. Other hyphæ, rising at right angles to the plane of the membranous portion of the mycelium, grow more and more attenuated, and branch at the tip; the terminal cells divide in two, as in Plate 1, Fig. 3, *c*, fall from their attachment, and germinate. This last modification of the hyphæ, which is by no means so common as the two previously described, will be recognized as corresponding to the so-called genus Helminthosporium, or Cladosporium, if we examine before the terminal cells have divided. It is out of the question to give specific names to such forms as those just described, which, since the publication of Tulasne's "Carpologia Fungorum," are known to be different states of development of species of Pyrenomycetes.

PYCNIDIA. — Besides the forms already described, there are other bodies of a more complicated nature. Plate 1, Fig. 3, *a*, *a*, represents the *pycnidia*, which are quite numerous in the spots, both on the leaves and the stems. Their general shape is spheroidal. They consist of a membranous sac of the same color as the darker parts of the mycelium, in which are contained the small bodies, which are represented as being discharged in Fig. 3, *b*. Their average diameter is .04 mm. In general appearance, the pycnidia resemble so closely those with which every one is familiar in other Pyrenomycetes, that any further description is unnecessary.

STYLOSPORES. — In examining the larger black spots on the stems of the olive, other bodies are seen, — the *stylospores*, to adopt Tulasne's nomenclature. They are represented in Fig. 1, *a*, and resemble flasks, whose long necks project beyond the mycelium, by which they are surrounded. They may be recognized by the naked eye, and clearly seen with a hand-lens, as the black projecting necks are tolerably conspicuous. To obtain a good view of them, some of the larger black spots must be picked to pieces, and the fragments treated with caustic potash, and afterwards hydrochloric acid. The shape of the separate

flasks is quite variable. The central portion of Fig. 1 represents one of the more regular, where, starting from a somewhat contracted base, there is a regular swelling of the central portion, which again diminishes into a rather long neck of uniform size. In some cases, the flask, instead of being straight, is flexuous with two swellings, the upper one being smaller than the lower. Others, still, fork, and usually one branch is much more obtuse than the other. The size of the flasks varies very much; but, even in their younger states, they can generally be distinguished from the pycnidia by being less inclined to a spherical shape. The height is as variable as the outline. Some of the smaller are .15 mm. high; others — and they are nearer the average — are .4 mm. The wall of the flasks is composed of dark-colored cells, which are longer in the direction of the axis of the flasks.

In some cases, the cells, composing the wall of the stylospores, grow outwards, so as to form papillæ; and, as the mycelium at the base generally sends up branches around the flask, it is only by a careful dissection that the base can be clearly seen. At first, the mouth is closed, and there is a depression of the cells at the centre; but, later, they spring back so as to form, round the open mouth, a circle of slightly reflexed teeth, whose tips are perfectly hyaline. The neck of the flask is hollow; but, in the swollen portion, spores are borne. They are oval, and divided into four parts by cross partitions. They are not contained in asci, but are attached to short filaments which line the surface of the base and lower portion of the sides of the flask. They escape readily through the open mouth; and slight pressure on the covering-glass generally causes a fresh discharge.

So far, we have spoken of the fungus as seen on the olive. The orange-leaves sent us are also covered with a black substance, which is not so much in spots as in powdery sheets upon both surfaces of the leaves, more particularly the upper. The attachment to the leaf is by no means as strong as in the olive; and the deposit can easily be scraped off, even without previous moistening. In fact, in some places it falls off on the slightest touch. No specimens of diseased orange-stems were received for examination. A microscopic examination shows why the deposit was more easily removed from the orange than the olive leaves. The smooth surface of the former gives no permanent attachment to the fungus, which, as we have before said, does not penetrate into the interior of the cells of the mother plant; while, on

the other hand, the hyphæ wind themselves tightly around the stalks of the stellate hairs of the olive, from which they cannot be removed. If the fungus should attack both oranges and olives, it is very evident why the latter would suffer much more than the former. Apart from the absence of hairs, which invariably constitute a large proportion of the scrapings of the olive-leaves, that from the orange-leaves is precisely identical, — the same moniliform hyphæ, bearing Macrosporium and Helminthosporium spore-like bodies, the same pycnidia and stylospores. Micrometric measurements only confirm the identity. On the orange-leaves sent me, there is a greater proportion of pycnidia, and a smaller proportion of stylospores, than in case of the olive-leaves; but that is, of course, an accidental difference, as the olive-leaves themselves vary. On the orange, the proportion of Helminthosporium-like spores is much greater than on the olive: but, from the facility with which the so-called secondary forms of fruit are produced in fungi, and their great variability, that is not a fact of any importance; and we can in the most decided manner affirm that the fungus is the same on both plants.

The first account of a fungus growing upon orange-trees, resembling in its habits that received from California, was given by Persoon, in his Mycologia Europæa, p. 10, published in 1822. His description of the new fungus is very briefly given in the following words: "Fumago Citri, late effusa crassiuscula nigro-grisea. Provenit in Europa meridionali ad folia Citri Medicæ, quæ sæpe tota induit." Later, Turpin published an account, with a figure, of a species which he also called Fumago Citri, which Montagne made the type of a new genus, Capnodium, published in the Annales des Sciences Naturelles, 3 série, tome 11, 1849. Montagne seems to have had doubts as to the identity of the Fumago Citri of Persoon with that of Turpin. Almost simultaneously with the publication by Montagne of his genus Capnodium, Berkeley and Desmazières published, in the Journal of the Horticultural Society of London, vol. iv. p. 252, an article "On some Moulds referred by Authors to Fumago." In this communication, there is the following description of the orange fungus briefly referred to by Persoon and Montagne: "Capnodium Citri, Berk. and Desm. Sparsum, setosum; peridiis elongatis; mycelio ramoso moniliformi pulcherrime reticulato; sporidiis oblongis minutis. Fumago Citri, Pers., Myc. Eur., vol. i. p. 10; Turpin l. c. On leaves of different species of Citrus. France: Persoon, Léveillé."

Of fungi occurring on olive-trees, we have an early account by Montagne in the Annales des Sciences Naturelles, 3 série, tome 12, 1849, of a fungus mentioned in the "Bull. Soc. centr. d'agric.," 2 série, iv. p. 267, under the name of Antennaria elæophila, which had been found at Perpignan in 1829, which caused ravages somewhat the same as the California fungus, and which had previously been referred by him to Cladosporium Fumago. It was probably the same plant as the Torula Oleæ of Castagne. Tulasne, however, in the "Carpologia Fungorum," vol. ii. p. 279, showed that the Friesian genus Antennaria was the pycnidial state of species of fungi of which Capnodium was the ascigerous state. He restored the old name, Fumago, and gave a detailed account of Fumago salicina, which was illustrated in his unrivalled manner.

The fungus from California is evidently the same as that which has been known in Europe since 1829. We have examined two authentic specimens of Antennaria elæophila Mont., — one from the Duby Herbarium, the other from that of De Notaris, — and the structure is precisely that of the pycnidial-bearing portion of the California fungus. The stylospore-bearing portion of our fungus is the Capnodium Citri of Berkeley and Desmazières, to which they refer the Fumago Citri of Persoon and Turpin. Montagne had observed only the pycnidial form — his Antennaria elæophila — on olives; whereas, on the orange, he found only the stylospore form, — his Capnodium Citri. Berkeley and Desmazières make mention only of stylospores on species of Citrus. We have been so fortunate as to find, on the specimens from California, both pycnidia and stylospores, and on both olives and oranges, — which proves the identity of Antennaria elæophila (Mont.) and Capnodium Citri (Berk. and Desm.). The perfect ascigerous state of the fungus we have not found; nor do Berkeley and Desmazières seem to have met with it, for they add to their description, "asci have not been observed." We have not been able to find any recorded instance of asci having been found in Capnodium Citri. Tulasne remarks, — quite pertinently, as it seems to us, — that, until better known, Capnodium Citri and Antennaria elæophila can scarcely be considered distinct from Fumago salicina.* The specimens from

* "Donec melius cognoscantur, a Fumagine salicicola supra descripta ægre etiam discriminantur, nisi sede sibi singulis assueta, tum *Fumago Citri*, Persoonio seu *Capnodium Citri* Montanio; tum etiam *Antennaria elæophila,* Montanio," &c. (Selecta Fungorum Carpologia, pp. 283, 284.)

California certainly seem to strengthen Tulasne's suspicions; and we must confess ourselves quite unable to distinguish between Fumago salicina — found on willows, oaks, birches, hawthorn, quince, and pear — and Capnodium Citri, found on oranges, and, as the Californian specimens show, also on olives. If it be said that no asci have been seen by us, that is no reason why the fungus should be removed from Fumago salicina, which, in the conformation of its mycelium, its conidia, pycnidia, and stylospores, it most closely resembles. Evidently, in the group of fungi which we are considering, too much stress must not be laid on the length and shape of the stylospores. We see, in the specimens before us, how great is the variation in what is undoubtedly a single species. Neither is the fact of the branching of the stylospores very significant, as, in the present case, there are both simple and branching stylospores. If the reader will compare our Plate 1, Fig. 1, with that of Fumago salicina, by Tulasne, "Carp. Fung.," Plate XXXIV., Figs. 14 and 20, — leaving out of sight, as far as possible, the different artistic merits of the two, — we think he will admit, that, in all essential particulars, they are alike. In reality, the resemblance is even greater than the limited size of our drawing would indicate. We have said that we found no asci; but Plate 1, Fig. 1, *c*, would seem to be the early stage figured by Tulasne, l. c., Fig. 20. The asci will probably be found in California; and we do not doubt that they and their contained spores will prove to be like those of Fumago salicina.

If we seem to the reader to have gone too minutely into the consideration of the systematic position of the fungus, it was for the purpose of bringing out more forcibly the fact that it is nothing new, or peculiar to California; and that it is not even limited to orange, lemon, and olive trees, but, as we have seen, is found on a number of other trees. How does it happen, then, that a fungus so widely diffused should suddenly increase to such an extent as to injure two important crops? We remarked, in passing, that the hyphæ seemed to be, as it were, gummed to the stellate hairs, and, in some cases, to one another, by a sticky substance. We do not forget, that, when any mycelium is growing on a leaf, a certain amount of dirt — including, of course, some oily matter — is sure to be entangled in its meshes. In the case of the present fungus, however, there is something more than an accidental accretion of such substances. The surface of the leaves

and stems is in many places covered with a gummy deposit, presumably of insect, certainly not of fungus, origin. On this gum, the fungus grows luxuriantly; and, although it may be found on those parts of the leaves where no gum can be seen, yet it is evident that it has reached such places by growing from the gummy spots. Of the origin of the gum, other than that it does not come from the fungus, we have no theory of our own to advance. Remains of insects are abundant on the leaves; but, being entirely ignorant of entomology, we cannot say what their relation is to the diseased trees. It may be that they are stray visitors caught in the gum. The fungus grows most luxuriantly on the remains of insects which I have seen, which, in some cases, present a ludicrous spectacle, the hyphæ projecting from them like the quills of a hedgehog.

It has often been asserted by botanists that fungi, of the group to which ours belongs, are particularly inclined to attack trees which have been previously infested with insects. In 1849, Berkeley, in the London Journal of Horticulture, described a fungus occurring in Ceylon on coffee, — Triposporium Gardneri, — which followed the appearance of a species of coccus which was described in the same journal by Mr. George Gardner. In their paper on moulds referred to Fumago, Berkeley and Desmazières make the following statement: "They are often, if not always, preceded by honey-dew, whether arising from aphides, or from a sugary excretion from the leaves themselves. Frequently, too, they are accompanied by some species of coccus, especially in the genus Citrus." Tulasne * does not agree with the writers just mentioned, as will be seen by the reference. He begins his description of Fumago salicina, however, with the following words: "Initio fungillus e membranula constat tenuissima, alba et hyalina, matricique vivæ instar gummi soluti illitus hæret, quamvis

* Quibusdam observatoribus visum est *Fumagines* in fructicibus potissimum provenire quos aphides primum occupassent, tamquam si ex humore dulci quem bestiolæ istæ emittunt, aut ex latice viscido quem matrix ab iis læsa copiosum aliquando stillat, suum pabulum traherent; necessitates autem hujus modi duplici de causa minime verisimiles censemus. Hinc enim sexcenties nobis contigit *Fumagines* luxuriantes videre in arboribus, omnis aphidum generis prorsus expertibus; illinc *Fumagines* vere parasitari constat, succis scilicet alienis uti ex his vivis. Super hoc argumento conferas tamen quæ attulit Berkelæus in tomo iv. (1849) Ephemeridis Soc. Hortic. Londinensium, nec non Georgio Gardner commentatiunculam ibidem (pp. 1–6) editam circa the Coffee-bug and Coffee-mildew. (Carp. Fung., ii. p. 280.)

ab eadem, maxime si fortuito ea aruerit, frustulatim aliquando secedat. Id cuticulæ struunt utriculi, perexigui, . . . oleo pallido tandem repleti," &c. This initial stage described by Tulasne is figured in Table XXXIV., Fig. 2, mm., l. c. We must confess that the expression, "matricique vivæ instar gummi soluti illitus hæret," seems a little indefinite, but the figure looks exceedingly like a collection of oil-globules, or very small eggs. We do not pretend to say that what Tulasne saw was not a membrane of vegetable substance, — a part of the fungus itself; but, in the Californian specimens, we had something which looked very much like the mm. of Tulasne's figure, and, in this case, we have satisfied ourselves, by observation and experiment, that it is of animal nature, and not a part of the fungus, which, instead, was growing upon it. It is a little difficult to understand, from what is already known of the development of fungi, how any fungus could begin as a very thin membrane, composed of small cells filled with oil. The initial stage of fungi, if we except the Myxomycetes, as far as we know, is filamentous, not membranous.

The result of our examination of the diseased orange and olive leaves is briefly as follows: The disease, although first attracting the eye by the presence of a black fungus, is not caused by it, but rather by the attack of some insect, which itself deposits some gummy substance on the leaves and bark, or so wounds the tree as to cause some sticky exudation, on which the fungus especially thrives. It is not denied that the growth of the fungus greatly aggravates the trouble already existing, by so encasing the leaves as to prevent the action of the sunlight: we only say, that, in seeking a remedy, we are to look further back than the fungus itself, — to the insect, or whatever it may be, which has made the luxuriant growth of the fungus possible. With regard to the fungus, we are able to assert that it is the same on both olives and oranges, — the species described by Berkeley and Desmazières under the name of *Capnodium Citri*, which seems to us, together with the pycnidial state described by Montagne under the name of *Antennaria elæophila*, to be but two states of a species identical with that described by Tulasne as *Fumago salicina*. It remains yet to find the asci on olives or oranges, which will probably be accomplished without difficulty in California. The earliest stages of the fungus should be studied by some one living near orange-groves; for, although the disease has been known to attack greenhouse plants, it is

not very common, or, in that case, so favorable for study. Especially is it to be desired that careful notes of the extent and manner of appearance of the disease, and the climatic and hygrometric conditions attending it, should be carefully recorded.

As a remedy, alkaline soaps, as strong as the trees will bear, will no doubt prove advantageous in case of the oranges; but, in the case of the olives, much less good is to be expected, owing to the presence of the stellate hairs on leaves and twigs. With this, our notice of the disease from a botanical stand-point ends; and we commend the subject to the attention of entomologists.

No. 22. — *On the American Grape-Vine Mildew.* By W. G. FARLOW, Assistant Professor of Botany in Harvard University.

THERE are, probably, no plants in general cultivation in this country which are attacked by a greater number of fungi, or rather by fungi to which a greater number of names has been given, than the different species of grapes. We have under cultivation not only our native species of Vitis with the fungi peculiar to them, but also the imported varieties of Vitis vinifera, accompanied, also, by their own special maladies. In his List of the Plants of North Carolina, Curtis enumerates no less than eighteen species of fungi found exclusively, or almost exclusively, on species of Vitis; and to this number might be added others which, although common on grape-vines, are also found on other plants. It is a mistake to suppose, however, that the species enumerated are all really distinct from one another. On the contrary, the genera, *Phoma*, *Diplodia*, *Septoria*, and others are nothing but secondary forms of genera of Ascomycetous fungi, of which several representatives, *Rhytisma Vitis*, Schw., *Tympanis viticola*, Fr., *Diatrype viticola*, Schw., *Valsa Vitis*, Schw., and others are found on our grape-vines; and it may appear, in the end, that the supposed variety of fungi is not so great after all; but, like the bill of fare presented by the obliging waiter, nothing more than ram, lamb, sheep, and mutton. We are, as yet, in ignorance as to exactly which of the ascigerous forms, the secondary forms belong, and, until we have a more complete knowledge of the subject, distinct, specific names will still continue to be given to the latter. It is to be hoped, however, that, the time is not remote when we shall have such a knowledge of the development of the different fungi which are found on the grape, as to enable us to dispense with the superfluous specific names which represent, as it is, our ignorance rather than knowledge.

The grape disease, properly speaking, that which has proved so disastrous at different times to the vines in Europe and Madeira, is caused by a fungus to which Berkeley has given the name of *Oidium Tuckeri*. All we know of this fungus botanically is, that it is the conidial form of some species of Ascomycetes, probably some *Erysiphe*. The perfect fruit has never been found on the vine in Europe. The

same *Oidium* has been reported in several places in this country; but, inasmuch as *Oidium Tuckeri* is the general name given to any white mould on grapes by those of our botanists who have not made a special study of fungi, the information is not always trustworthy. Undoubtedly a form undistinguishable from the *Oidium Tuckeri* of Europe does occur in this country,* but to what extent is uncertain. During the past summer, the grape-vines at Amherst, Mass., were attacked by a fungus which was supposed to be *Oidium Tuckeri*, and which was distributed as such. The fungus was the *Uncinula spiralis* of Berkeley and Curtis, of which the conidia are almost, if not quite, identical with *Oidium Tuckeri*. Perithecia were abundant on the specimens we have examined, and the connection between conidia and perithecia could be traced. We are not aware that the perithecia of *Uncinula spiralis* have ever been found in Europe, and it is doubtful whether the fungus of the European vines is really that species. At any rate, it must be admitted that, as used in this country, the name *Oidium Tuckeri* is somewhat indefinite, and does not necessarily refer to the same fungus as in Europe. Whatever forms may, correctly or incorrectly, be included under *Oidium Tuckeri*, as far as our experience goes, none of them is by any means as common, certainly not in New England, as another fungus, *Peronospora viticola*, B. & C., which is limited to the leaves and stems, and does not attack the fruit. This fungus is peculiar to America, and we have attempted in the following pages to give a history of its development.

Although extremely common, the fungus in question is not one very likely to attract the attention of those not somewhat interested in fungi. It first appears on the under surface of the leaves, which, in most of our native species of Vitis, is so covered with whitish wool that the fungus, which is of nearly the same color, escapes notice. Later, it causes a curling and drying up of the leaf, which then passes for any ordinary dead leaf. The fungus makes its appearance about the first of August; and, at any time from the middle of the month until frosty weather sets in, one can be almost certain of finding it. As we

* In the Curtis Collection the only American specimen of Oidium Tuckeri is one marked 3723 on Vitis rupestris, Texas, Lindheimer. No. 3610, Michener (538) on Vitis Labrusca, Pennsylvania, 1851, and Nos. 292 and 399 Russell, Mass., September, 1856, on cultivated grape-vines, are the original specimens of Uncinula spiralis, B. & C.; and a figure of the asci and appendages is given in Berkeley's "Introduction to Cryptogamic Botany," p. 278, fig. 64.

have already said, it makes its appearance first on the under surface of the leaves, most abundantly on the veins near the petioles, and afterwards in spots all over the under surface. It is most easily recognized on *Vitis cordifolia*, where the under surface of the leaves is smooth, and where the frost-like substance of the fungus is in strong contrast with the green leaf on which it grows. When growing on *Vitis Labrusca*, *V. æstivalis*, or cultivated varieties of those species, it appears in the form of spots, at first pure white, afterwards rusty, slightly raised above the level of the hairs with which the lower surface of the leaves is clothed. Sometimes, and, except in *Vitis cordifolia*, we have not found it to occur at all frequently, the fungus invades the petioles of the younger leaves and the stems which swell to considerably more than their usual dimensions. As the disease advances, the fungus spreads over the whole of the lower surface of the leaves, until, as not unfrequently happens, scarcely a healthy leaf remains; red spots appear, at first small, afterwards larger; the leaf becomes dark brown, shrivels up, and becomes very brittle, but it does not fall from its attachment at once, as we should expect. The fungus, like all the other species of the genus, flourishes best in moist warm weather, but seems more tolerant of dryness than any other Peronospora with which we are acquainted. We have allowed leaves to remain exposed for some days on a table in the dry atmosphere of a laboratory, and fresh conidia were produced for several days even when the leaf seemed quite dry. During August, the disease, in the region of Boston, advances gradually until, towards the middle of September, almost every leaf is affected and hangs dead upon the branches.

MYCELIUM. — A microscopic examination of the leaves and stems shows an abundance of mycelial threads or hyphæ. They are from .008–.0122 mm. in diameter in the stem and petioles, but are generally smaller in the leaves. In the stem, their general course is up and down, and they are found in all parts, except the wood proper where they do not penetrate. The contents of the hyphæ are granular and somewhat oily, and there are but rarely any cross partitions. They force their way in all directions between the parenchymatous cells, and into them by means of haustoria, Plate II., Fig. 3, *a*, which are abundant, especially in the stem. The haustoria are usually not more than half the diameter of the hyphæ, and resemble strongly those of *Cystopus candidus*, being spherical and connected with the hyphæ

by slender necks. A magnifying power of three hundred diameters is sufficient to show them plainly. In the leaves, the hyphæ are found in all parts except the vascular bundles, and are more irregular in diameter than in the stem, being often swollen in a varicose manner. Just beneath the stomata, the hyphæ are particularly abundant and intricately entangled. Those which are destined to bear the conidia pass through the stomata being constricted in their passage and expanding afterwards, so that when cut off from the surface of the leaf they seem to have a bulbous base. Sometimes such a large number of hyphæ force their way through a single stoma that the two cells which bound it are torn asunder.

However large a number of hyphæ may force their way through, a small number, from four to eight, grow faster than the rest and bear the conidia. The conidia-bearing hyphæ vary from .2 to .6 mm., in height when fully matured. Their general habit of branching is shown in Plate II., Fig. 1. The tip of the simple axis divides into three parts, one of which generally seems like the direct termination of the axis and the other two as lateral offshoots, given off at about the same level. At the base of each of the two lateral offshoots, two similar secondary offshoots are again given off as shown in Plate II., Fig. 2, which represents a highly magnified view of a tip of a stem in which *a* denotes the primary divisions and *b* the secondary. The third division of the primary branch on the left is behind, and concealed from the observer by the branch itself. The same form of division takes place at the tip of the branches and their subdivisions, so that the ultimate ramifications always seem three-parted. The branches, which are few in number, generally from four to eight, are placed alternately on the upper third of the axis, being generally, but not always, distichously arranged. Relatively to the main axis, they are all short, the broadest expansion from side to side not being usually greater than .12 mm. The branches are furnished with branchlets of a second and third order as shown in Plate II., Fig 1, where the naked lower portion of the stalk has been only partly represented. The general arrangement of the conidia-bearing hyphæ, it will be noticed, is more compact than in most species of Peronospora, the ultimate branchlets being very dense. The conidia are borne in profusion on the tips of the hyphæ. They are of an oval shape, obtuse, and without the papilla found in some species at the remote end, but slightly

acute, and with a short projecting point at the attached end. Their size is very variable, the smaller being .0085 mm. by .0125 mm. and the larger about .017 mm. by .03 mm.

Germination. — The germination of the conidia was studied by us in the beginning of October, when the fungus was in its prime. Leaves affected with the fungus were gathered in the afternoon, and allowed to remain under a moistened bell-glass during the night. In the morning, parts of the leaves where fresh conidia had grown during the night were cut out, and the conidia shaken into watch-glasses, or on to glass slides containing a few drops of water. In order to test the conditions of germination, some of the bell-glasses were placed in a light room, and others kept in the dark, and sowings were made at different hours of the day. The result was uniformly the same, whether the conidia were in the dark or the light. Experiments in direct sunlight were, however, unsuccessful, as the sun's rays heated the water to such an extent as to cause rapid evaporation of the necessarily small amount of water used. With relation to the time of day at which the sowing was made, germination took place in all cases; but the conidia sown in the morning generally germinated somewhat more quickly and more abundantly than those sown in the afternoon. This might have been partly owing to the fact, that the conidia sown in the morning were in better condition, the result of a growth of fourteen or fifteen hours; while those sown in the afternoon were the conidia produced during only four or five hours of the forenoon. It was not possible to keep the conidia which were produced in the night until the afternoon, as they generally fell from their attachments in the morning, and began to germinate. In all cases, the germination took place with a surprising regularity. At the end of an hour, the conidia were slightly swollen and their contents had begun to segment, as shown in Plate III., Fig. 4, each segment having a light-colored nucleus. At the expiration of an hour and a quarter, the segments had resolved themselves into a number of oval bodies, which collected at the distal end of the conidia, and which, before long, succeeded in rupturing the cell wall and making their escape from the mother-cell. They passed out rather slowly, usually one at a time, and paused for a moment in front of the opening, where they remained as if not yet quite free from one another. In a short time each segment began to extricate itself from the common mass, moved more and more actively,

and, finally, darted off with great rapidity a full-fledged zoöspore furnished with two cilia. The number of zoöspores produced in a conidia is very variable. The most frequent number is five or six. Sometimes there are not more than three, and we counted in one case seventeen. Not unfrequently one or two of the zoöspores do not succeed in escaping from the mother-cell, but they are seen to move about inside. Where two remain, it often happens that, by trying to move in opposite directions, they prevent one another from passing out at the open mouth of the conidia. The shape of the zoöspores can hardly be described, as it is continually changing. Plate III., Figs. 6, 7, show two of the most common forms which they assume. At times, they are irregularly oval, flattened on one side, and more acute at one end than at the other. There are always two bright spots near the flat edge, from which two cilia project in opposite directions. In other cases, the zoöspore rolls itself up into a ball, the two bright spots are brought almost in contact with one another, and the cilia project nearly parallel to one another. Plate III., Fig. 7. The length of the zoöspores varies from .008 mm. to .010 mm. They move about for from fifteen to twenty minutes, the motion growing gradually slower. At the end of that time they come to rest, the cilia drop off, they assume a spherical shape; and, in about a quarter of an hour, an outgrowth appears on one side which develops rapidly into the mycelium of a new plant. Under no circumstances have we seen any direct production of a hypha from the conidia itself as sometimes happens in *Peronospora infestans.*

The regularity and punctuality with which germination takes place, notwithstanding the variations in light, heat, and other external conditions, is quite surprising. It is so regular that by properly arranging the time of sowing, and first making sure that the conidia used are quite ripe,* we are able to be tolerably certain of a crop of zoöspores for class demonstration at any given hour. At the end of an hour, or an hour and a quarter, the conidia will have begun to swell; a quarter of an hour later, the zoöspores will have been discharged; in another quarter of an hour they will have come to rest; and in another quarter of an hour they will have begun to germinate. Time and time again have we sat with watch open before us to observe

* To make sure of this, it is better to shake a piece of a diseased leaf over the water to be used, rather than to plunge it into the water.

the changes which might occur from the end of the first hour until the beginning of the following quarter-hour; and almost punctually to the minute, the discharge of zoöspores has begun. When the conidia sown are in good condition, the greater part of them emit their zoöspores during an interval not greater than fifteen or twenty minutes; and those which during this period do not discharge their contents in the form of zoöspores do not do so at a later period, but abort. When the conidia are sown in the afternoon, however, it sometimes happens that a part of them do not germinate until the next morning.

OÖSPORES. — We have found the oöspores of *Peronospora viticola* only on plants of *Vitis æstivalis*, where they are apparently abundant, although not very easily seen. They are found in the latter part of September and October, in the discolored, shrivelled parts of the leaves, and are most abundant just inside what are called the palisade cells of the upper surface. They are spherical, about .03 mm. in diameter, have a thick cell wall, which is smooth and slightly yellow in color, and almost completely fill the mother-cell, as shown in Plate III., Fig. 2. The dense structure and opacity of the upper surface of the leaf and the dense woolly covering of the lower surface, which can be entirely removed only with great difficulty, renders this species one of the least favorable of the genus for the study of the formation of the oöspores. In dried specimens, the oöspores can be well seen only after boiling in potash, afterwards treating with hydrochloric acid, and a careful dissection, a process, it will be easily imagined, likely to distort the parts.

The oöspores are generally set free by the cracking open, or, more slowly, by the rotting of the palisade cells, which allows the escape of the oöspore with its tough covering. The germination of the oöspores we have not been able to discover.

The fungus we are now considering is very abundant on *Vitis æstivalis*, Michx., *V. Labrusca*, L., and all their cultivated varieties; on *V. cordifolia*, Michx.; on *V. vulpina*, L., and the cultivated Catawba grape; and, in fact, on nearly all varieties of American grapes, although we have not as yet heard of its occurring on the Diana grape. It is probably found throughout the whole United States east of the Rocky Mountains, but it has not yet been reported from the west coast. It has been said not to occur on the smooth-leaved species, but its presence on *V. cordifolia* proves the contrary. It has also been said that it does not

occur on the varieties of *V. vinifera* growing in this country. As we have not had an opportunity in this region of examining such varieties growing in the open air, we cannot controvert this point; but our experiments prove that it can be made to grow on *V. vinifera* even more luxuriantly than on American species.

To study the propagation of the disease, leaves of different species were kept under moistened bell-glasses, and conidia were sown on them in different positions. The quickest method of infection was by laying a healthy leaf upon one affected with the fungus. In two cases, the fungus appeared on the healthy leaf at the end of the second day. It made no difference whether the upper or lower surface of the healthy leaf was brought in contact with the infected leaf, as far as the contagion was concerned. Again: germinating zoöspores were sown on the upper and lower surfaces of healthy leaves of *Vitis vinifera*, and of smooth-leaved American species. The fungus appeared first on the leaves of *V. vinifera*, on the fifth day after sowing, and grew luxuriantly, soon covering the leaves. On American species, it made its appearance a day or two later. Where the zoöspores were sown on the leaf, the best results were obtained when sown on the lower surface. This is, perhaps, owing to the fact that the under surface of the leaves is concave, and readily holds the water used in the cultures, while the upper surface is somewhat convex.

In order to find out in what way the hyphæ produced from the zoöspores make their way into the vine, small slices of petioles were placed on moistened slides, on which were germinating conidia. In only one case was a direct result obtained; and then the germinal thread passed through the epidermis, and not through a stoma. On this point, however, our experiments were not sufficiently numerous to prove satisfactory.

One would naturally suppose that a fungus so common as *Peronospora viticola*, which often is found on every leaf of a vine, would have an injurious effect upon the grape crop. Such, however, is not the case. The fungus does not attack the grapes themselves; nor does it, at least in New England, appear until about the first of August; and its withering effect upon the leaves is not very evident before September. As far as out-of-door grape culture in the Northern States is concerned, we are inclined to believe, that, practically no harm is done by *Peronospora viticola*, but that, on the contrary, the fungus

is really beneficial. Our native vines have a luxuriant growth of leaves; and the danger is that, in our short summers, the grapes will not be sufficiently exposed to the sun to ripen. But the Peronospora arrives, with us, at a period when the vine has attained its growth for the season; the important point being then to ripen up the grapes which are concealed by the foliage. By shrivelling up the leaves, the Peronospora enables the sun to reach the grapes without loss to the vines, as is shown by the fact that the vines continue to live on, year after year, without apparent injury. Should the fungus be introduced into Central Europe, the case might be different. The foliage of *Vitis vinifera* is by no means as luxuriant as that of our own vines; the winters are warmer, the springs earlier, and the summers much moister, than here; and it is quite possible that the advent of the Peronospora, by reason of the greater warmth and moisture, would be some weeks earlier than here, before the vine had attained its growth, and at a time when the leaves are needed for the work of absorption and assimilation. It might be that the introduction of *Peronospora viticola* into Europe would prove a repetition, on a small scale, of what has, unfortunately, already happened in the case of Phylloxera. The presence of *Peronospora viticola* is no protection against what is in this country called *Oidium Tuckeri*, for we have found both plants growing side by side on a leaf of *Vitis cordifolia.*

The fungus we are now considering was probably first collected by Schweinitz, who erroneously considered it *Botrytis cana*, Lk., in his "Synopsis Fung. Am. Bor.," 2663, No. 25. In the Curtis collection is a Schweinitzian specimen marked *Botrytis cana*, on a grape-leaf. The specimen is well preserved, and there is no doubt of its being the genuine *B. viticola.* The species was named *B. viticola* by Berkeley and Curtis, from specimens collected in 1848, and distributed without a description by Ravenel in his "Fung. Car. Exs.," V. 90. It was referred to by Caspary, in "Monatsbericht der Berliner Akademie," May, 1855; and by Sprague, in "Proc. Bost. Soc. Nat. Hist.," Jan. 6, 1858. It was first described by De Bary, in the "Annales des Sciences," 4th series, 20th volume, p. 125, 1863, as follows: "*P. viticola* (Berk. et Curt.), mycelii tubi crassi, sæpe constricti varicosique (haustoria non vidi). Stipites conidiferi fasciculatim e stomatibus emergentes, graciles, elati, summo apice parum attenuato brevissime semel bisve dichotomi v. trifurcati; sub apice ramos plerumque, 4–6

(raro 3, v. 7) gerentes. Rami primarii plerumque alterni, distantes et exacte distichi, omnes pro stipitis altitudine breves; inferiores plerumque trifurcati divisionibus iterum bis trifurcatis v. quandoque bis dichotomis; ramuli ultimi (quarti) ordinis, æque ac stipitis divisiones apicales, brevissime conico-subulati recti, acuti. Rami primarii superiores minores, inferiorum secundariis v. tertiariis conformes. Rami omnium ordinum angulis rectis patentes, primarii in uno plano divaricati, planum ramificationum secundi ordinis in primario, tertiarorum in primario et secundario perpendiculare. (Rarius rami primarii 2 inferiores oppositi sunt, raro ramulis 2 alterius muniti nec trifurcati, rarissime rami primarii irregulariter sparsi nec distichi sunt.) Conidia parvula, ovoidea, apice lato rotundata v. subtruncata, papilla destituta, membrana circumcirca æquali hyalina. Oögonia parva, membrana tenui hyalina v. lutescente oösporam foventia subglobosam episporio tenui fuscente diaphano lævi munitam."

It is again referred to as a Botrytis by Curtis, in his "List of Plants of North Carolina," 1867; by Peck, in the "Twenty-third Report of the N. Y. State Botanist," for 1869 (pub. 1873); and by Frost, in Tuckerman's "Catalogue of Plants within Thirty Miles of Amherst College," 1875, and Berkeley, in "Grevillea" for March, 1875, "Notices of N. A. Fungi," No. 667, gives the following description:

"*Peronospora viticola*, B. & C. Floccis candidis sursum ramosissimis apicibus breviter emarginatis furcatisve; sporis ovatis. On the under-side of leaves of *Vitis æstivalis*. Santee River, Ravenel, No. 1632; New England, Sprague, No. 5764; Missouri, Dr. Engelmann. Forming orbicular white spots; flocci articulated, much branched above; the apices emarginate, or shortly forked and acute; spores ovate. In those varieties where the leaves are woolly beneath, the spots are less conspicuous."

Although our plant has been considered quite distinct among the species of *Peronospora*, it seems to us that one cannot fail to see a decided resemblance to *P. nivea*, Unger. The conidia differ from those of the latter species in being smaller, and in not having an apical papilla, but resemble them, and those of *P. infestans*, in their mode of germinating. The conidial-bearing hyphæ in *P. viticola* are taller, and comparatively more slender, than in *P. nivea;* but the peculiar tripartite division of the tips, so uniform in *P. viticola*, is also frequently found in *P. nivea*, although in the latter they are much more

attenuated, not densely compact, as in the former. The oöspores of the two species are very much alike. In short, one might almost say that *P. viticola* was *P. nivea*, with the axis and primary branches drawn out, and the ultimate branches contracted.

It has seemed to us desirable to give at the close of the present article an account of the species of Peronospora at present recognized in the United States, although we can make but a beggarly display compared with European countries. It is natural to suppose that our list will be increased as collectors of fungi shall hereafter turn their attention more especially to plants of this order. But, however many species may be added to the number already known, there can be no doubt that the number of individuals is much smaller than in Europe. We have found it difficult to secure specimens for class demonstration, which is never the case in Central Europe, where, early and late, one is tolerably certain of finding several species. *P. parasitica*, Pers., as far as our experience goes, is not common; and we have never found it in company with *Cystopus candidus* on *Capsella*. *P. gangliformis*, Berk., is one of our few comparatively common species; and, unfortunately for market gardeners, it bids fair to become still more common. *P. viticola* must, on the whole, be considered our commonest species, although *P. infestans* is periodically very abundant. In this connection we would call the attention of our readers to the discovery of the oöspores of *Peronospora infestans* by Mr. Worthington G. Smith, in the leaves of American varieties of potatoes, for which he has been awarded a gold medal by the Royal Horticultural Society, of England. As the results of Mr. Smith's discovery have lately appeared in several journals, some of which are accessible to most of the readers of the Bulletin, we need only refer them to the "Gardener's Chronicle" of July 17, 1875, the "Journal of Horticulture and Cottage Gardener," July 22, the "Quarterly Journal of Microscopic Science," for October, 1875, where two photographs are given, and to the "Journal of the Royal Agricultural Society of England," 2d Series, Vol. 11, Part II., No. XXII., where a review of the subject is given by W. Carruthers, F. R. S.

SYNOPSIS OF THE PERONOSPOREÆ OF THE UNITED STATES.

PERONOSPORA.

CONIDIA solitary, borne on the tips of branching filaments, which pass through the stomata into the air. Oöspores spherical, buried in the tissues of the foster-plant.

PERONOSPORA INFESTANS (Mont.), *Botrytis*, *Auct.*, *De Bary*, *Annales des Sciences*, 4 *Sér.* *Tom.* XX., 1863. Potato-rot fungus. Mycelium slender, haustoria few, conidial-bearing hyphæ irregularly swollen at intervals near the tip. Branches few, irregularly placed, conidia ovoid, apex papillate. Germination usually by means of zoöspores. Oöspores (*Artotrogus hydnosporus*, Mont. fide Berkeley), dark brown, coarsely reticulated. Vide W. G. Smith, " Quarterly Journal of Microscopic Science," Oct. 1875.

Common on potatoes in all the Atlantic and Middle States. In California, near San Francisco, May, 1875, Dr. H. W. Harkness. On tomatoes, Ravenel, South Carolina, September and October, 1859.

PERONOSPORA NIVEA, UNGER. *De Bary*, *l. c. No.* 2. *P. Umbelliferarum*, *Caspary*, *Monatsbericht*, *Berliner Akad. May*, 1855. *P. macrocarpa Rabenh. Herb. Mycol.* Mycelium torulose. Haustoria numerous, oval. Conidial-bearing hyphæ, fasciculate, 3 to 7 from each stoma. Axis short, simple; branches few, short, at right angles to axis. Tips of ultimate branches loosely bi- or tri-partite. Conidia ellipsoidal, obtusely papillate. Germination by zoöspores. Oöspores rather large, numerous, epispore hyaline or slightly yellow. Plate II., Fig. 4, and Plate III., Figs. 9, 10.

To this species we refer a fungus found by us twice, once at Cambridge, near Fresh Pond, on the under surface of the leaves of *Geranium maculatum*, L., in August, 1874, and again at Wood's Hole, Mass., on the same plant, July, 1875.* It forms large pure white patches between the principal veins. There are two *Peronosporæ* found on species of *Geranium* in Europe, *P. pusilla*, Unger, and *P. conglomerata*, Fuckel. The latter is very different from our species. The former, for a specimen of which, collected by Professor De

* Since the above was sent to press, we have found the same species of *Peronospora* on a leaf of *Geranium Robertianum* amongst the undetermined species of the Curtis Collection, No. 58, without date or locality.

Bary, we are indebted to Dr. C. E. Stahl, is more like our plant, yet different. Of *P. nivea*, Unger, we have a number of specimens on *Ægopodium Podograria*, collected near Strassburg; and, in spite of the fact that, as a rule, the species of *Peronospora* are limited to particular species of phanerogams, or nearly related species, we can see absolutely no difference between European specimens on an Umbellifer and our own on Geranium. De Bary describes *P. nivea* as being only rarely tripartite at the tip, while our European specimens are as often tri- as bi-partite. The same is true of American specimens. The shape and size of the conidia is the same in both specimens. In both the apex is obtusely papillate; and, if there is any difference in the oöspores, it is that the epispore of American specimens is a little the thicker. We have, unfortunately, never seen the germination of the conidia in American specimens.

Peronospora viticola, B. & C. *Botrytis cana, Herb. Schw. De Bary, l. c. No.* 40, *Berkeley, Not. N. A. Fungi, Grevillea, March*, 1875. Ravenel Fung. Car. Exc. V. 90. Grape mould. Mycelium varicose, haustoria abundant, small, spherical. Conidial-bearing hyphæ fasciculate 4–10 from each stoma, axis simple, slightly undulate, branches few on the upper part of axis, short, alternate, beset with secondary and tertiary branchlets. Tips closely tripartite. Conidia oval, destitute of terminal papilla. Germination by zoöspores. Oöspores numerous, small, epispore smooth, slightly yellow. Plate II., Fig. 1. Plate III., Figs. 2—8.

Common in the Atlantic and Central States on *Vitis Labrusca*, L., *V. æstivalis*, Michx., *V. cordifolia*, Michx., *V. vulpina*, L., and their cultivated varieties. Oöspores on *V. æstivalis.*

Peronospora gangliformis, Berk. *Journal Hort. Soc. London*, 1, *p.* 51, *tab.* 4, *De Bary, l. c. No.* 6. Lettuce mould.

Mycelium slightly torulose. Haustoria ovate, conidial-bearing hyphæ several times dichotomous, slender, swollen at the tip into a round or slightly funnel-shaped body, from the circumference of which radiate several, two to eight, processes, which bear the small roundish conidia. Germination by a terminal tube. Oöspores small roundish, epispore thin, yellow.

Common on lettuce, Watertown, Mass. On *Lactuca altissima*, Bot. Gard. Cambridge, 1874. On *Nabalus albus*, Wood's Hole, Aug. 1875.

Peronospora parasitica, Pers. *De Bary, l. c. No.* 7. Mycelium large. Haustoria very large, branching. Conidial-bearing hyphæ repeatedly dichotomous. Ultimate divisions slender, divaricate. Conidia ellipsoid obtuse. Germinal tube given off from any part of conidia. Oöspores round; epispore, slightly yellow, smooth, or slightly rugose.

Cabbage leaves. Society Hill, N. C. March, 1849. Curtis, No. 2259. On *Cardamine rhomboidea,* D. C. Buffalo N. Y., Clinton in 26th Report of N. Y. State Botanist, by Peck. *Lepidium Virginicum,* L., Noank, Conn., Aug. 1875.

Peronospora effusa, Grev., *De Bary, l. c. No.* 16. — Mycelium cylindrical. Haustoria filiform. Conidial-bearing hyphæ repeatedly dichotomous. Divisions of ultimate dichotomy unequal, flexuous, recurved. Conidia large, ellipsoidal, dirty-violet, colored. Germination by a lateral tube. Oöspores globular; epispore dark-colored, with irregular projections.

To this species we refer two specimens found among the undetermined fungi of the Curtis collection, labelled "Atriplex, Albany." Besides these, we found at Newton, Mass., August, 1874, a *Peronospora* on the under-surface of leaves of *Plantago major*, with both oöspores and conidia, which is apparently the same species as that on the Atriplex, and which agrees perfectly with European specimens of *P. effusa*, Grev., although that occurs on *Chenopodiaceæ* and *Polygonaceæ*. *P. alta*, Fuckel, of which the oöspores are unknown, occurs on the leaves of *Plantago major*, and the description answers very well to our plant. We must confess, however, that the description of that species also answers remarkably well for our European specimens of *P. effusa* on Chenopodium; and we must consider that our plant whose conidia germinate by means of a lateral filament is *P. effusa*, rather than the somewhat doubtful *P. alta*.

It is possible that the onion-disease so destructive in Connecticut is caused by *Peronospora Schleideniana*, Unger, which is injurious to onions in Europe. We have not, however, been able to examine specimens of the Connecticut disease; nor do we know of any scientific investigation of the subject.

CYSTOPUS.

Conidia in rows, packed closely together, and bursting through the epidermis in spots. Oöspores as in *Peronospora.*

Cystopus candidus (Pers.), *Uredo Auct.* (White-Cabbage Mould). Conidia of uniform size, round. Oöspores large, round, yellowish, marked with flexuous ridges, sometimes reduced to rough papillæ. Common on cruciferous plants, Atlantic and Central States. On *Capsella bursa pastoris, Dentaria epiphylla, Sinapis nigra* (oöspores), *Turritis,* &c.

Cystopus Bliti, Bivon, *C. Portulaceæ (D. C.), De Bary, l. c. Nos. 3 and* 4. Conidia of two kinds, — the terminal larger than the rest, and generally sterile; the rest cylindrical ovoid. Oöspores large, round. Epispore dark-brown, marked with slightly elevated ridges, which, at maturity, form a net-work. Common on different species of *Amaranthus* and on *Portulaca oleracea.*

Cystopus cubicus, Mart., *Uredo candida, var. Auct. Berkeley, Not. N. A. Fungi, Grevillea, Dec.,* 1874. Conidia of two kinds, — terminal large and sterile; the rest short, cylindrical. Oöspores round, dark-colored, densely covered with small protuberances. On *Convolvulus panduratus, Ipomœa trichocarpa.* On *Convolvulus macrorhiza,* Ohio (vid. Berkeley l. c.). On *Ambrosia artemisiæfolia,* Newton, August, 1874. We should be thankful that there is one fungus, at least, which is injurious to this troublesome weed.

Cystopus spinulosus, De Bary, has been detected by Peck on Cirsium, collected by Hon. G. W. Clinton, near Buffalo, N. Y.

No. 23. — *List of Fungi found in the Vicinity of Boston.* By W. G. FARLOW, Assistant Professor of Botany in Harvard University.

THE following list makes no pretension to completeness, as will be seen by the small number of species of Basidiomycetes and Ascomycetes reported. It is intended simply as a contribution to our knowledge of the fungi found in the neighborhood of Boston, of which our only sources of information are the papers by Mr. C. J. Sprague, published in the "Proceedings of the Boston Society of Natural History," March 5, 1856, and Jan. 6, 1858, and numbered references to the collections of Mr. C. J. Sprague, Mr. Dennis Murray, and the late Rev. J. L. Russell, in the "Notices of North-American Fungi," by the Rev. M. J. Berkeley, now in course of publication in Grevillea. Of the present list, the species have all come under our own observation within a radius of a few miles of the Bussey Institute, or at Wood's Hole, Mass., where the University summer course in cryptogamic botany was given in the months of July and August, 1875. Occasionally, reference is made to a species from a more remote locality. We have omitted the names of a large number of conidial forms which are known to be states of ascomycetous fungi, since one specific name is, of course, sufficient to indicate a whole series of forms. The nomenclature of the species of *Myxomycetes* has been made to correspond, as far as possible, with that adopted by Dr. J. T. Rostafinski, in his work on that group.

MYXOMYCETES.

CERATIUM HYDNOIDES, A. & S. Newton; Wood's Hole. Common.

CERATIUM PORIOIDES, A. & S. Wood's Hole.

LYCOGALA EPIDENDRON, Fr. Common near Boston. On stumps.

TUBULINA CYLINDRICA, D.C. Newton. On pine stumps.

CRIBRARIA VULGARIS, Schrad. Newton.

CRIBRARIA PURPUREA, Schrad. Eastport, Me. October, 1875.

DICTYDIUM CERNUUM, Schrad. Newton. Rather common.

RETICULARIA MUSCORUM, Fr. Eastport, Me. October, 1875. On stumps.

STEMONITIS FUSCA, Roth. Common near Boston.

STEMONITIS FERRUGINEA, Ehrb. Newton. Common.

LAMPRODERMA COLUMBINUM, Rostafinski. (*Physarum*, Pers.) Eastport, Me. October, 1875.

TILMADOCHE NUTANS, Rostafinski. (*Physarum*, Pers.) Newton; Wood's Hole.

PHYSARUM FARLOWII, Rostafinski. Newton.

PHYSARUM SINUOSUM, Rostafinski. (*Angioridium*, Grev.) Newton; Wood's Hole.

LEOCARPUS VERNICOSUS, Lk. Newton; Wood's Hole. Common.

FULIGO SEPTICA, Rostafinski. (*Æthalium*, Fr.) Common near Boston.

DIDYMIUM CLAVUS, Fr. Bussey Woods.

DIDYMIUM XANTHOPUS, Fr. On moss and dead leaves. Wood's Hole. Common.

DIDERMA GLOBOSUM, Pers. Wood's Hole. On leaves. Common.

TRICHIA CHRYSOSPERMA, D.C. Newton. Common.

TRICHIA PYRIFORMIS, Hoffm. Newton.

HEMITRICHIA CLAVATA, Rostafinski. Newton.

ARCYRIA PUNICEA, Pers. Common.

ARCYRIA NUTANS, Grev. Newton. Wood's Hole. Rather common.

ARCYRIA CINEREA, Fl. Dan. Newton.

LACHNOBOLUS GLOBOSUS, Rostafinski. (*Arcyria*, Schw.) Newton. Common on chestnut burrs and leaves.

MUCORINI.

MUCOR SYZYGITES, De Bary. (*Syzygites megalocarpus*, Ehr., and *Sporodinia grandis*, Lk.) Common on decaying agarics. Wood's Hole; Newton.

MUCOR MUCEDO, L. On all decaying substances.

MUCOR RACEMOSUS, Fres. On horse-dung. Bussey Inst.

MUCOR STOLONIFER, De Bary. (*Ascophora mucedo*, Tode; *Rhizopus nigricans*, Ehr.) On decaying articles of food everywhere.

MUCOR PHYCOMYCES, Berk. (*Phycomyces nitens*, Kze.) Found by Dr. C. F. Folsom in the sewers of Boston; also growing luxuriantly at the Bussey laboratory from specimens sent from Strassburg by Dr. Stahl; Cambridge, on bones.

THAMNIDIUM ELEGANS, Lk. Bussey Inst. On horse-dung.

CHÆTOCLADIUM JONESII, Bk. and Br. Bussey Inst. On horse-dung.

PIPTOCEPHALIS FRESENIANA, De Bary. Bussey Inst. On horse-dung.

MORTIERELLA POLYCEPHALA, Van Tieghem. Bussey Inst. On horse-dung.

PILOBOLUS CRYSTALLINUS, Tode. Bussey Inst. and Cambridge. On horse-dung. Very common.

PERONOSPOREÆ.

Cystopus candidus, Lev. Bussey Inst.; Wood's Hole; Newton. Common on cruciferous plants. Oöspores on Sinapis nigra. Noank, Conn.

Cystopus cubicus, Lev. Conidia and oöspores on Ambrosia artemisiæfolia. Newton.

Cystopus Bliti, Bivon. Common near Boston on species of amaranth.

Peronospora infestans, Mont. Common on potatoes near Boston.

Peronospora viticola, B. & C. On wild and cultivated grape-vines. Common near Boston.

Peronospora nivea, Unger. Cambridge, near Fresh Pond; Wood's Hole. On leaves of Geranium maculatum.

Peronospora gangliformis, Berk. Common on lettuce, Watertown. On Nabalus albus. Wood's Hole.

Peronospora parasitica, Pers. On Lepidium Virginicum. Noank, Conn.

Peronospora effusa, Grev. On leaves of Plantago major. Newton.

UREDINEÆ.

Uromyces macrospora, B. & C. On Lespedeza capitata. Newton; Bussey Woods.

Uromyces Ari (Schw.). On Arisæma triphyllum. Common near Boston.

Uromyces appendiculata, Lev. Bussey Inst. On bean-leaves.

Uromyces apiculosa, Lev. On clover.

Uromyces Hyperici (Schw.). Bussey Woods.

Melampsora salicina, Lev. On willows. Very common near Boston.

Melampsora betulina, Desm. On birches. Common near Boston.

Melampsora populina, Lev. On Populus. Common near Boston.

Puccinia variabilis, Grev. On Nabalus albus. Wood's Hole.

Puccinia Valantiæ, Pers. On Galium. Bussey Woods.

Puccinia Circeæ, Pers. On Circæa Lutetiana.

Puccinia Helianthi, Schw. On leaves of Helianthus annuus. Noank, Conn. Bussey Inst.

Puccinia Prunorum, Lk. On Prunus serotina, and other species of Prunus. Common near Boston.

Puccinia striola, Lk. On species of Carex. Bussey Woods.

Puccinia Graminis, Pers. Everywhere.

Puccinia Sorghi, Schw. Newton.

Puccinia Asteris, Schw. On leaves of Aster. Newton.

Puccinia Peckiana, Howe. On Rubus occidentalis. Bussey Woods.

Puccinia Anemones, Pers. On Anemone nemorosa. Newton; Bussey Woods. On Thalictrum cornuti, New Haven, Conn.

Phragmidium triarticulatum (B. & C.). Newton. Common on leaves of Potentilla Canadensis.

Phragmidium mucronatum, Lk. On cultivated-rose leaves. Bussey Inst.; Newton.

Podisoma macropus, Schw. On Juniperus Virginiana. Common near Boston.

Cronartium asclepiadeum, Fr. On Comptonia asplenifolia. Newton; Wood's Hole.

Imperfect Forms belonging to the Uredineæ not included in the Species enumerated above.

Æcidium myricatum, Schw. On leaves and stems of Myrica cerifera. Wood's Hole. August.

Æcidium conorum Piceæ, Rees. This rare fungus was found on two green cones of Abies excelsa, Newton, July, 1874. It is certainly an æcidial form, as has been shown by Rees.

Uredo Vacciniorum, Schw. Bussey Woods.

USTILAGINEÆ.

Ustilago segetum, Pers. Newton.

Ustilago Maydis, Lev. Common on corn. Everywhere.

Ustilago utriculosa, Tul. On Polygonum. Jamaica Plain, Mass.

Urocystis occulta, Preuss. On rye. Newton.

Urocystis pompholigodes, Sch. On leaves and petioles of Anemone nemorosa. Bussey Woods.

BASIDIOMYCETES.

Sub-order *Gasteromycetes.*

Sphærobolus stellatus, Tode. Newton; Wood's Hole. Common.

Cyathus striatus, Hoffm. Bussey Woods.

Crucibulum vulgare, Tul. Common on sticks near Boston.

Mitremyces lutescens, Schw. Newton. Rare. New Haven. Prof. D. C. Eaton.

Scleroderma vulgare, Fr. Common near Boston.

Bovista plumbea, Pers. Wood's Hole; Gay Head.

Lycoperdon pyriforme, Schæff. Common near Boston.

Lycoperdon gemmatum, Batsch. Common near Boston.

Lycoperdon cœlatum, Bull. Wood's Hole. Common. Newton.

Lycoperdon Bovista, L. Newton. Not common. Cambridge.

Phallus impudicus, L. Common near Boston; Wood's Hole.

Phallus indusiatus, Bosc. New Haven, Conn. Prof. D. C. Eaton.

Sub-order *Hymenomycetes.*

Dacrymyces stillatus, Fr. Common near Boston.

Tremella foliacea, Pers. Common near Boston.

Calocera cornea, Fr. Newton.

Clavaria Botrytis, Pers. Newton; Wood's Hole.

Clavaria cristata, Holmsk. Wood's Hole.

Clavaria formosa, Pers. Newton; Wood's Hole.

Clavaria abietina, Schum. Newton; Wood's Hole.

Clavaria amethystina, Bull. Newton; Wood's Hole.

Clavaria fusiformis, Sow. Newton.

Cyphella fulva, B. & R. Bussey Woods.

Solenia villosa, Fr. Newton.

Corticium amorphum, Fr. On spruce. Newton.

Corticium Oakesii, B. & C. Newton.

Stereum complicatum, Fr. Bussey Woods.

Stereum purpureum, Pers. Common near Boston.

Stereum hirsutum, Fr. Common near Boston.

Stereum acerinum, Fr. Newton.

Stereum tabacinum, Fr. Newton.

Thelephora anthocephala, Bull. Wood's Hole; Newton.

Thelephora Cladonia, Fr. Wood's Hole.

Thelephora pallida, Schw. Wood's Hole; Newton. Common.

Thelephora terrestris, Ehr. Wood's Hole.

Craterellus cornucopioides, Pers. Common near Boston.

Kneiffia setigera, Fr. Newton.

Irpex sinuosus, Fr. Common near Boston.

Irpex cinnamomeus, Fr. Common near Boston.

Hydnum imbricatum, L. Wood's Hole. Common.

Hydnum repandum, L. Common near Boston.

Hydnum compactum, Fr. Wood's Hole; Newton. Not very common.

Hydnum aurantiacum, Fr. Newton.

Hydnum ferrugineum, Fr. Newton; Wood's Hole. Not uncommon.

Hydnum zonatum, Batsch. Wood's Hole; Newton. More common than the last.

Hydnum adustum, Schw. Newton. Tolerably common.

Hydnum auriscalpium, L. On fir-cones. Wood's Hole.

Hydnum (Hydnoglœum, Curr.) gelatinosum, Scop. Winchester, Mass.

Hydnum ochraceum, Pers. Common near Boston.

Fistulina hepatica, Fr. On stumps. Newton. Mason's Island, Conn. Not common.

Merulius lacrymans, Schum. Very common in cellars.

Glœoporus nigropurpurescens, Schw. Newton. Tolerably common.

Dædalea confragosa, P. Newton; Bussey Woods.

Dædalea unicolor, Fr. Everywhere common on stumps.

Polyporus vaporarius, Fr. Newton. Common.

Polyporus vulgaris, Fr. Common near Boston.

Polyporus medulla-panis, Fr. Newton.

Polyporus mucidus, Fr. Newton.

Polyporus contiguus, Fr. Newton. Common.

Polyporus pergameneus, Fr. Bussey Woods.

Polyporus versicolor, Fr. Everywhere.

Polyporus hirsutus, Fr. Common near Boston.

Polyporus cinnabarinus, Fr. Newton, on cherry-trees. Not very common near Boston.

Polyporus igniarius, Fr. Newton; Bussey Woods.

Polyporus fomentarius, Fr. Everywhere common.

Polyporus conchifer, Schw. Common on elm-trees near Boston.

Polyporus adustus, Fr. Bussey Woods.

Polyporus gilvus, Fr. Newton.

Polyporus lacteus, Fr. Newton.

Polyporus epileucus, Fr. Bussey Woods. Common.

Polyporus sulfureus, Fr. Newton; Bussey Woods.

Polyporus cristatus, Fr. Newton. Not common.

Polyporus frondosus, Fr. Bussey Woods.

Polyporus lucidus, Fr. Cambridge; Winchester.

Polyporus Curtisii, Berk. Newton.

Polyporus elegans, Fr. Common near Boston.

Polyporus Boucheanus, Fr. Newton; Wood's Hole. Tolerably common.

Polyporus perennis, Fr. Newton; Wood's Hole. Common.

Polyporus Schweinitzii, Fr. Newton; Bussey Woods; Cambridge, near Fresh Pond.

Polyporus lucidus, B. & C. Near Bussey Inst.

Boletus strobilaceus, Scop. Newton. Rare. Wood's Hole. Common.

Boletus scaber, Bull. Common near Boston.

Boletus edulis, Bull. Common near Boston.

Boletus luridus, Schæff. Newton; Wood's Hole.

Boletus purpureus, Fr. Newton; Wood's Hole.

Boletus retipes, B. & C. Cambridge.

Boletus parasiticus, Bull. On Scleroderma. Cambridge, near Fresh Pond.

Boletus bovinus, L. Newton. Common.

Lenzites tricolor, Fr. Newton. Common.

Lenzites betulina, Fr. Everywhere.

Lenzites Berkeleii, Lev. Bussey Woods.

Lenzites Cratægi, Berk. Newton; Bussey Woods.

Lenzites sepiaria, Fr. Common near Boston.

Schizophyllum commune, Fr. Common near Boston.
Xerotus nigrita, Lev. Bussey Woods; Eastport, Me.
Panus conchatus, Fr. Newton.
Panus stypticus, Fr. Common everywhere near Boston.
Lentinus Lecontei, Fr. Bussey Woods.
Marasmius oreades, Fr. Common near Boston.
Cantharellus cibarius, Fr. Wood's Hole.
Cantharellus tubæformis, Bull. Newton. Common.
Cantharellus (Trogia) crispus, Fr. Newton; Bussey Woods.
Russula alutacea, Fr. Common near Boston.
Russula emetica, Fr. Newton.
Russula virescens, Fr. Wood's Hole; Newton. Common.
Lactarius piperatus, Fr. Common near Boston.
Lactarius vellereus, Fr. With the last.
Lactarius Indigo, Fr. Wood's Hole.
Lactarius subdulcis, Fr. Common near Boston.
Hygrophorus cinnabarinus, Fr. Wood's Hole.
Hygrophorus coccineus, Fr. Common on moss near Boston.
Hygrophorus psittacinus, Fr. Newton.
Cortinarius violaceus, Fr. Wood's Hole. Common.
Cortinarius sanguineus, Fr. Newton. Common.
Coprinus comatus, Fr. Cambridge, in gardens. Not common.
Coprinus atramentarius, Bull. Cambridge.
Coprinus micaceus, Fr. Common near Boston.
Coprinus radiatus, Bolt. Common on horse-dung.
Agaricus fascicularis, Huds. Very common.
Agaricus sylvaticus, Schæff. Wood's Hole.
Agaricus campestris, L. Common.
Agaricus tener, Schæff. Common.
Agaricus squarrosus, Müll. Bussey Woods.
Agaricus prunulus, Scop. Newton.
Agaricus ostreatus, Jacq. Newton.
Agaricus laccatus, Scop. Very common.
Agaricus melleus, Vahl. Very common.
Agaricus granulosus, Batsch. Winchester, Mass.
Agaricus cristatus, Bolt. Newton.
Agaricus procerus, Scop. Wood's Hole. Common.
Agaricus vaginatus, Bull. Newton. Common.
Agaricus strobiliformis, Vitt. Newton.
Agaricus muscarius, Fr. Common near Boston.

ASCOMYCETES.

Sub-order *Perisporiaceæ.*

Sphærotheca Castagnei, Lev. On Bidens frondosa, Taraxacum, and Spiræa opulifolia. Near Boston. Common.

Phyllactinia guttata, Lev. On Quercus, Alnus, Corylus, and Carpinus leaves. Very common. Also on barberry-leaves. Newton.

Uncinula adunca, Lev. On willow-leaves. Common.

Uncinula spiralis, B. & C. On grape-vines, Amherst, Mass.

Uncinula circinata, C. & P. On leaves of Acer rubrum. Common near Boston.

Podosphæra Kunzei, Lev. On Spiræa salicifolia and S. tomentosa, and on different species of Prunus. Common.

Microsphæria Russellii, Clinton. On Oxalis stricta. Newton.

Microsphæria extensa, C. & P. On oak-leaves, near Bussey Inst.

Microsphæria pulchra, C. & P. On Cornus alternifolia. Common near Boston.

Microsphæria Hedwigii, Lev. On Sambucus Canadensis, near Bussey Inst.

Microsphæria penicillata, Lev. On Carpinus, near Bussey Inst.

Microsphæria Friesii, Lev. On Syringa vulgaris. Common near Boston.

Erysiphe lamprocarpa, Lev. Common on Compositæ.

Erysiphe Martii, Lk. On peas. Bussey Inst.

Erisiphe communis, Schl. On Baptisia tinctoria, Ranunculus, Chelone glabra, &c. Common.

Eurotium herbariorum, Lk. Everywhere.

Sub-order *Tuberaceæ.*

Elaphomyces variegatus, Vitt. Newton. Rare.

Elaphomyces granulatus, Fr. Bussey Woods, Jan., 1876.

Penicillium crustaceum, Fr. Everywhere.

Sub-order *Helvellaceæ.*

Morchella esculenta, Pers. Newton. Not very common.

Geoglossum hirsutum, Pers. Newton; Wood's Hole. Common.

Mitrula paludosa, Fr. Newton. Common.

Leotia lubrica, Pers. Common near Boston.

Peziza hemispherica, Wigg. Wood's Hole.

Peziza macropus, Pers. Newton; Wood's Hole.

Peziza scutellata, L. Common near Boston.

Peziza aurantia, Fr. Common on the ground near Boston.

Peziza æruginosa, Fr. Common near Boston.

Peziza vulgaris, Fr. Common near Boston.

Peziza nivea, Fr. Common near Boston.

PEZIZA VIRGINEA, Batsch. Wood's Hole.

ASCOBOLUS FURFURACEUS, Pers. On dung. Bussey Inst.

BULGARIA INQUINANS, Fr. Newton; Wood's Hole.

BULGARIA SARCOIDES, Fr. Newton.

EXOASCUS PRUNI, Fuckel. On plums. Cape Ann.

Sub-order *Phacidiacei.*

RHYTISMA SOLIDAGINIS, Schw. Wood's Hole.

RHYTISMA ACERINUM, Fr. Newton. Common.

Sub-order *Pyrenomycetes.*

TORRUBIA SPHINGUM, Tul. Wood's Hole. Not common.

TORRUBIA MILITARIS, Fr. Rather common near Boston.

TORRUBIA OPHIOGLOSSOIDES, Tul. On Elaphomyces variegatus. Newton. Rare.

TORRUBIA CAPITATA, Fr. On Elaphomyces granulatus. Bussey Woods. Not common.

CLAVICEPS PURPUREA, Tul. On Glyceria and rye. Common.

HYPOMYCES LACTIFLUORUM (Schw.). Common near Boston.

HYPOMYCES LUTEO-VIRENS, Tul. On Boletus. Common near Boston.

HYPOMYCES CHRYSOSPERMUS, Tul. Common near Boston.

HYPOMYCES ASTEROPHORUS, Tul. On Nyctalis. Newton. Wood's Hole.

NECTRIA CINNABARINA, Fr. Very common on dead twigs.

XYLARIA POLYMORPHA, Grev. On stumps. Common.

XYLARIA HYPOXYLON, Grev. Common.

USTULINA VULGARIS, Tul. Common on dead wood.

HYPOXYLON COCCINEUM, Bull. Bussey Woods.

HYPOXYLON FUSCUM, Fr. Common on dead wood.

HYPOXYLUM NUMMALARIUM, Bull. Common.

DOTHIDEA ULMI, Fr. Very common.

DOTHIDEA GRAMINIS, Fr. Everywhere.

DIATRYPE STIGMA, Fr. Common.

DIATRYPE DISCIFORMIS, Fr. Common.

SPHÆRIA MORBOSA, Schw. Very common on plum and cherry trees.

SPHÆRIA SUBICULATA, Schw. Newton.

SPHÆRIA POTENTILLÆ, Schw. Common on P. Canadensis.

CUCURBITARIA BERBERIDIS, Gray. Bussey Woods.

PLEOSPORA HERBARUM, Rabh. Everywhere.

PLEOSPORA CLAVARIARUM, Tul. Bussey Woods.

MONOSPORA VULGARIS, Tul. On conidia of Torrubia militaris. Newton.

IMPERFECT FORMS.

DIPLODIA MEGALOSPORA, B. & C. On spruce cones. Newton.

PESTALOZZIA GUEPINI, Desm. On cranberry leaves. Newton.

Botryosporium pulchrum, Corda. On Dahlia stems. Newton.

Helminthosporium inflatum, B. & C. Newton.

Streptothrix atra, B. & C. On Juniperus Virginiana. Newton. Common.

Rhinotrichum Curtisii, B. On dead wood. Newton. Wood's Hole.

Zygodesmus olivascens, B. & C. On the ground. Wood's Hole.

Zygodesmus fuscus, Corda. Newton. Wood's Hole.

Tricothecium roseum, Fr. Common, Bussey Institution.

Arthrobotrys oligospora, Fres. Bussey Institution.

Volutella ciliata, Fr. On potatoes. Bussey Institution.

No. 24.— *The Black Knot.* By W. G. Farlow, Assistant Professor of Botany in Harvard University.

Without doubt, the most striking disease of vegetable origin occurring on fruit-trees in this country is that commonly known as the black knot. The disease takes its name from the unsightly, black, wart-like excrescences with which every one is familiar on plum-trees and different kinds of wild and cultivated cherries. It is found in all parts of our country east of the Rocky Mountains, and is so common and destructive, that, in some districts, one seldom sees a plum-tree free from the knot. An idea may be formed of the small crop of plums now raised in New England from the fact, that two dollars and a half were given in Boston last autumn for a peck of damsons for preserving. In some parts of New England, particularly in Maine and along the sea-coast, the raising of cherries has also been almost abandoned in consequence of the ravages of the black knot. The disease is peculiar to America, and has been the bane of fruit-growers from early times; but, although much has been written in agricultural papers about its injury to the fruit crop, the subject has been almost entirely neglected by botanists. In the present paper, we shall consider the cause and prevention of the knot, and the question whether the disease is the same on plums and cherries. As a preliminary step, it will be well to trace the development of the knot as it occurs on a single species, and, for this purpose, the choke cherry, *Prunus Virginiana*, L., may be selected.

The choke cherry abounds in all the hedges and thickets of New England, and is recognized by its thin ovate or obovate, abruptly acuminate leaves, and reddish, harsh-tasting fruit, in racemes. In winter, its branches are generally plentifully covered with the knots, which are partly concealed by the foliage in summer. They are black, and vary in size from half an inch to eight or ten inches, or even a foot, in length, and are about two inches in circumference. In some cases, they completely surround the branch on which they are growing, but more frequently they extend only part way round; their course, when very long, being usually somewhat spiral round the stem. If they

extend completely or nearly completely round the branch, the portion above the knot dies. Frequently the upper part of the stem bends over so as to form a right angle with the lower part, and sometimes the portion involved in the knot forms an irregular coil. The surface of the knot is undulated, and flakes of bark not unfrequently adhere to it. In winter, it is more or less cracked and broken open, and the inside is seen to be worm-eaten and hollow, except the woody portion of the stem, which passes through, comparatively sound, generally on one side of the knot.

Below and above the knot, unless the branch above have been completely killed, the stem is swollen for from half an inch to two inches, rarely for a greater distance. Under the microscope, sections show, that, although the bark has been cracked in several places by the expansion of the stem, yet a new layer of bark has formed over the exposed portions. An abundance of mycelial threads are seen extending in streaks from the cambium towards the cuticle. At their outer extremity the bundles of mycelial threads spread out into fan-shaped masses, as shown in Plate VI., Fig. 1. The threads are hyaline, very fine, .0007 mm. in diameter, and are most intricately twisted together in bundles, so that it is almost impossible to say whether there are any cross partitions in them. In longitudinal sections, it is easy to see that they begin in the cambium, and radiate outwards. The threads are found only in the swollen part of the stem; and on the most careful search we have been unable to detect any in the stem, just below the swelling.

CONIDIA. — As spring advances, the mycelial threads increase in size, burst through the bark, and then form the dense pseudo-parenchymatous tissue characteristic of the *Pyrenomycetes* when about to fructify. The knot grows larger, until, about the time the choke cherry flowers, it has nearly the same diameter as the knot of the year before, of which it is an extension. It is not, however, black, but a very dark brownish green. It is solid, rather pulpy, and, on section, a number of radiating lines are seen, as shown in Plate IV., Figs. 2 and 3. With a hand lens, one can see small hemispherical protuberances, which are the beginnings of the perithecia. The whole surface of the protuberances is covered with filaments (Plate V., Fig. 2 *b*), about .04 mm. to .06 mm. in height, and .004 mm. in breadth, which are somewhat flexuous, and frequently divided by cross parti-

tions. The filaments are more frequently simple, but sometimes branch. At the tip of the terminal joint, or more frequently a little to one side, is borne a spore, .006 mm. in length, ovate, and rather sharply pointed at the lower end. Not unfrequently two or three spores are borne on the upper joint, and others may also be produced on some of the lower joints. We have never seen any cross divisions in the conidial spores, which fall very easily from their attachments. The conidia which we have just described spring directly from the surface cells of the perithecia. They continue to bear their spores until the latter part of summer, when they begin to dry up, and, as winter sets in, one finds only their shrivelled remains. The conidia, it will be seen, are of that form which constitutes the genus *Cladosporium* of the older mycologists, or at times the threads are so flexuous as to remind one of species of *Streptothrix*. The genus *Cladosporium*, long ago lost all claims to autonomy, the forms included in it having been shown by Tulasne and others to be the secondary forms of different *Sphæriaceæ*. *Streptothrix*, represented by *S. atra*, B. and C., a common species of this country, will in all probability soon share the fate of *Cladosporium*.

ASCOSPORES. — As the summer advances, the knot grows larger, harder, and more brittle, and is usually attacked by insects of different species, which destroy the central part of the knot, leaving the black outer shell.

It is not until winter, however, that the spores are produced in the asci of the fungus. If we make a section of the outer part of the knot late in the autumn or early in the winter, we shall find that the perithecia are so far developed that one can see the young hyaline asci which line them. We have made no search for a carpogone, as it is evident that the fungus under consideration, owing to its dense, opaque substance, is one of the least favorable for the study of that organ. The asci grow slowly during the winter, and about the middle of January the spores begin to ripen. In the month of February, they are found in perfection; but late in spring they are not so abundant, or in such good condition. We first found a few ripe spores on the 17th of January; and, in the second week of February, most of the knots examined contained ripe spores. In the manner of their production in the asci, the present spores do not differ from those of the other *Pyrenomycetes*. There are eight in each ascus, and they

are discharged through a terminal pore. They are often arranged in a regular row, but quite as often they overlap one another irregularly. The asci themselves are about .12 mm. long, and are rather abruptly contracted at the base. The paraphyses are longer than the asci, unbranched, and club-shaped at the tip. The spores measure from .016 mm. to .02 mm. in length, and from .008 mm. to .010 mm. in breadth. They are two-parted, as shown in Plate VI., Figs. 5 and 6; one division being uniformly much smaller than the other, and not more than one quarter or one third as long. The spores are transparent, and slightly granular. As they lie in the ascus, the small end almost invariably points downward. Spores which ripen in February germinate in the course of from three to five days, when kept sufficiently moist. The first germinal tube grows invariably from the larger of the two divisions of the spore, and generally at the end farthest removed from the smaller division; a second tube grows from the smaller end; and not unfrequently others grow from the sides of the larger division. It must be remarked, that the germinating threads have a diameter three or four times as great as that of the hyphæ in the knot itself.

Stylospores. — Besides the perithecia, with their asci and spores, there are other reproductive bodies found, but not so frequently as the former. Between the ascus-bearing perithecia, we occasionally find cavities whose walls, not so thick as those of the perithecia, are lined with the stylospores, represented in Plate V., Figs. 4 and 5. They sometimes cover the whole surface of the cavity; but more frequently, they are in tufts, or on a sort of irregular placenta, which forms ridges on the walls. The stylospores, using Tulasne's nomenclature, are on very slender hyaline pedicels of different lengths. They are oval, .012 mm. long, by .006 mm. broad, and divided by cross partitions into three parts. When perfectly ripe, they are of a slightly yellowish tinge. The stylospores are of that form which was classed by older writers under the genus *Hendersonia*, which, like *Cladosporium*, is now recognized only as a secondary form of certain *Sphæriaceæ*. We are not able to refer the present form to any described species of *Hendersonia*, and none has hitherto been supposed to be associated with the fungus causing the knot.

Spermagonia. Pycnidia. — In winter and spring we find, besides the asci and the stylospores, bodies which must be classed under the

head of spermagonia. Plate VI., Fig. 2, represents a section through a cavity hardly distinguishable externally from the perithecia, which, instead of being filled with asci, is lined with slender filaments, whose tips are somewhat incurved, and easily break off, the central part of the sac being filled with them. We call these spermagonia, from their resemblance to the bodies of the same name in lichens. They are much less common than the conidia, or stylospores. Interspersed amongst the ascus-bearing perithecia, one finds, tolerably frequently, still other cavities which are much more flattened than the perithecia; which often, instead of appearing oval, on section, seem almost triangular. They are lined with short, delicate filaments, which end in a minute oval, hyaline body. These small oval bodies are produced in immense numbers, and are discharged not singly, but in masses. They are more or less closely held together by a sort of jelly, and ooze out from the cavity in which they were produced in the form of tendrils; reminding one of the toy called "Pharaoh's serpent." We have watched the emptying of these bodies, to which we must apply the somewhat vague name of pycnidia, and have found that it sometimes takes as long as two minutes for them to discharge their contents.

If we turn now from the knot on the choke cherry to that on the cultivated cherry and plum, we find a slight difference of aspect, so that, without much trouble, one can say whether a certain knot comes from a cherry or a plum tree. The difference is, however, slight, and not greater than would arise from the different character of the bark through which the fungus has to make its way. A microscopic examination of the knot, in its different stages, shows absolutely no difference between the fungus on cherries and on plums. The conidia are the same, and appear at about the same time; the ascospores are identically the same in both cases, and ripen at the same time; and the mycelium is the same. In short, the microscope fails to show any difference; and, if to the naked eye there appears to be any, it is, as we have said, owing either to the different histological character of the stems of the two trees, or to the greater luxuriance of the growth on one tree than on the other. On the whole, the fungus does not thrive so well on the plum as on the choke cherry, as is shown by the fact that fewer perithecia are formed on the former than on the latter, — a fact observed long ago by Schweinitz.

The knot on the plum is, moreover, attacked early in the season by insects, which modifies its development to a certain extent. The curculio, which makes its appearance early in July, stings the knots as well as the plums, and in the middle of July there exudes from both a gummy substance in great abundance. This gummy substance in a few days becomes covered with the common mould, *Tricothecium roseum*, Lk., which gives its pinkish tinge to a large part of the surface of the knot. On some plum-trees, one can hardly find a knot which has not some of the pinkish color caused by the presence of the *Tricothecium*, which has no organic connection whatever with the fungus which causes the knot, but is simply parasitic on it. It is probably owing to the fact that the curculio stings the knots, that so many persons have been led to believe that the knots themselves are of insect origin. We were greatly astonished last summer, while studying the development of the disease on a certain plum-tree, which, until the first of July, had progressed just as in the neighboring choke cherries, to find, after an absence from town of about ten days, that the whole aspect of the plum knots had been changed by the attacks of the curculio, so that they were hardly recognizable, owing to the gummy masses upon them; while the knot on the cherries remained unchanged. The *Tricothecium* almost immediately made its appearance, and remained on some of the knots until winter.

Anatomy of the Knot. — The histological character of the knot, at its perfection, is very much the same no matter upon what species of *Prunus* it is growing. The granulated surface is composed of the stroma of the fungus we have described, and the mycelium passes inwards in intricately wound bundles, which run in the direction of the medullary rays, and which vary in extent at different stages of growth. The fungus begins to grow in the cambium, either by prolongation from the mycelium of a knot directly above, or by the germination and growth of spores which have fallen on the bark. When the mycelium occupies the cambium of the greater part of the circumference of the stem, the branch above the knot dies, just as though it were girdled. More frequently, the mycelium is found in the cambium of only a part of the circumference of the stem, and that which is free from the mycelium goes on producing wood and bark as usual; and, if in midsummer or winter we make a cross section of a knot on a branch more than a year old,

we shall find one more layer of wood on the sound side of the stem than on the side of the knot. In other words, on one side, the formative power of the cambium has expended itself in forming a new layer of wood and bark (Phloem), and, on the other, irritated by the presence of a fungus, it has produced a mass, the knot, in which all distinction between wood and bark has been lost. In the knot we find bast fibres, wood cells, and dotted ducts; but the prevailing tissue consists of a collection of dotted, rectangular, parenchymatous, cells, with very thick walls, which closely resemble the cells of the medullary rays. These thick-walled cells, by their excessive growth, push the prosenchymatous cells out of their natural direction, parallel with the axis of the branch, and at intervals force their way through them, so that the latter seem to form a series of arcs of circles with the concavities outward. The dotted ducts are numerous, shorter than in the healthy part of the stem, and, owing to the abnormal position into which they are forced, cross sections of the stem frequently show them in lateral view, rather than in section. The separate dotted ducts, instead of lying side by side as usual, are closely twisted or braided together. The bast fibres are less altered in their direction and appearance than the other elements of the stem. The mycelial threads of the fungus form bundles, which are imbedded in the parenchyma of the knot.

The condition of the interior of the knot, in its later stages, is modified very much by the depredations of insects, as well as by the drying and crumbling of the tissue itself. On the wild cherries, the outer part is generally a mere shell, and the internal part is nearly empty. On the plum, the interior is more apt to be honeycombed; and we not unfrequently have a very hard layer next the wood, composed of thick-walled, dotted cells. The knot on cultivated cherries is intermediate between that on the wild cherries and that on plums. The condition of the interior of the knot has an important bearing on the propagation of the disease. Where it is hollow, and the outer part brittle, as in the choke cherry, it is easy to see that the spore-bearing portion will readily be broken up, and the spores blown about without difficulty. Where it is more solid, as in the plum, the spores will be dispersed with much less ease; and we can see how, by the action of the curculio in boring into the knot and making its tissue more spongy, it is facilitating the dispersion of the spores of the fungus when they shall ripen;

and, on the other hand, the knot tends to increase the number of curculios, by offering a suitable place for the deposit of their eggs. As a rule, the trees once attacked by the knot grow more and more diseased, both by the extension downwards and upwards on the stem of the old knots, and by the production of new ones from the germination and growth of spores of the old knots on other branches which have been previously free from them. More and more of the smaller branches are killed by the girdling effect of the knots; and the nutrition of the larger branches is evidently so decidedly impaired, that to bear fruit is entirely out of the question; and, after lingering in a diseased condition for a few years, the trees themselves die. We cannot say certainly for how many years a given knot may continue to elongate; because the older parts crumble, and leave no distinct mark by which the annual growth may be traced. One can, however, often recognize knots which have been growing for at least three years. In a few cases the branches seem able to recover from the knots, and the scars which indicate the previous seat of the disease can be seen.

The fungus causing the knot was first described by Schweinitz, in his "Synopsis Fungorum Carolinæ Superioris," under the name of *Sphæria morbosa*, in the following words: "S. cæspitosa astoma maxima receptaculo bullato fusco, sphærulis minoribus irregularibus albofarctis." At the time Schweinitz wrote, nothing was known of secondary forms of fruit in the *Sphæriæ*. The conidia were first described by Mr. C. H. Peck, in a paper on Botany, read as a report before the Albany Institute, February 6, 1872. He describes the conidial spores as "at first simple, but soon becoming one or more septate." We have never seen them other than simple; but, judging from other Cladosporioid conidia, we should expect the spores to divide at some time. Since Schweinitz's day, the genus Sphæria has been more or less cut up by writers into different genera; and the question naturally occurs, To which of them shall we refer Schweinitz's *Sphæria morbosa?* Curtis, in his Catalogue of Plants of North Carolina, still calls it a *Sphæria;* and places it in the division *Erumpentes*, subdivision *Cæspitosæ*, between *S. nobilis*, B. & C., and *S. Perisporioides*, B. & C., to which, more particularly the latter, it bears but little resemblance. Mr. C. B. Plowright, in "Some Remarks upon Sphæria Morbosa," in the "Monthly Microscopical Journal" for May, 1875, thinks it should be placed in

the genus *Gibbera* near *G. Vaccinii*, Fr. It seems to us, on the whole, premature, so long as the complete history of so many of the different *Sphæriaceæ* remains unknown, to place much confidence in generic characters of that order as at present defined. In estimating the systematic position of any fungus, we must consider all its different states, and any classification based solely on one form of fruit, to the exclusion of others, must be unsatisfactory. The species of *Gibbera* have not yet been sufficiently studied to enable us to define the genus accurately; and we should think it more correct to place the *Sphæria morbosa* of Schweinitz in the genus *Cucurbitaria*, some of the species of which — as *C. Laburni*, De Not., — it resembles in the stylospores and pycnidia, although the ascospores are different. The ascospores of the different species of *Cucurbitaria*, however, vary very much in appearance. We prefer to retain the generic name *Sphæria* for the present, and wait until the genera of *Sphæriaceæ* assume a more definite character, before changing it.

Turning, now, from the botanical side of the case, to the knot as a destroyer of fruit-trees, there is no end to the articles which have appeared in the journals, speculating on its cause or suggesting a remedy. We occasionally hear that the knot is a recent disease; but Mr. J. Buell states * that, in 1811, the plum-trees in Kingston, Mass., were almost all destroyed by the knot. Schweinitz,† speaking of its effects in 1822, says: "Morbum lethalem Cerasorum et omnium Prunorum effecit." In 1831,‡ he again refers to the *Sphæria morbosa* as being much more common in Pennsylvania than in Carolina, and as being particularly injurious to cherries, which he calls in Latin "Amarellæ," probably Morellos, and to the Hungarian and Reine Claude plums. From the sentence, "Nuperrime autem et in his omnibus Cynips fungusque incepiunt sævire et quidem magnitudine semper maxime aucta, sistentes tumores ad sesquipedalem longitudinem extensos," it appears that he regarded the black knots as caused by the combined action of insects and *Sphæria morbosa*. In 1819, Prof. W. D. Peck, of Cambridge, published an account of the insects found in the knots of cherry-trees, which he regarded as the cause of the knot itself. Dr. Joel Burnett, of Southboro', Mass.,§ was one of the first to

* "New England Farmer," Jan. 20, 1826.

† "Syn. Fung. Car.," p. 40, No. 134.

‡ "Syn. Fung. Am. Bor.," p. 204, No. 1416, 269.

§ "New England Farmer," Aug. 16, 1843.

assert that the knot was caused by a fungus rather than an insect, although his belief that the fungus originated in a morbid condition of the plum itself was incorrect. In the second edition of his "Insects Injurious to Vegetation," Harris is somewhat non-committal, although he goes so far as to admit, that, "whatever be their [the knots] origin and seat, they form an appropriate bed for the growth of numerous little parasitical plants or *fungi*, to which botanists give the name of Sphæria morbosa." He also significantly adds: "It is worthy of remark, that they are sure to appear on the warts in due time, and that they are never found on any other part of the tree."

More recently, the belief in the insect origin of the knots has been given up by entomologists, although it is still generally held by fruit-raisers. One of the most prominent entomologists who has, in recent years, written on the nature of the black knot, is Mr. B. D. Walsh.* He is of the opinion that the knot is not caused by any insect, but by a fungus whose spores ripen in July. From this statement, we might infer that he had seen the conidia, although he does not describe them so that they can be recognized. If, however, what he saw were the conidia, his statement that they extend down over the stem below the knot is incorrect. He went too far in asserting that there were two distinct kinds of black knot: one on plums, and another on cherries. He was led to this conclusion, apparently, rather by statements of other persons as to the communicability of the disease from plums to cherries, and *vice versâ*, than from any direct observation on the structure of the knot. In a review of Walsh's article,† the writer goes still farther from the fact in suggesting that there is a third kind of fungus on *Prunus Chickasa.*

The best and so far as we know the only correct statement of the etiology of the black knot, was made by Mr. C. H. Peck,‡ who, as we have already remarked, was the first to describe the conidial state of the fungus. He also first showed definitely when the ascospores ripened, and correctly reasoned that the knot was caused by the *Sphæria morbosa*, and that the fungus on plums and cherries was the same.

* "The Practical Entomologist," March 26, 1866, and March, 1867.

† "Entomologist and Botanist," Vol. II., p. 231.

‡ A Paper on Botany read as a Report before the Albany Institute, February 6, 1872.

The reasons for believing that the knot is not caused by insects may be summed up as follows: First, the knots do not resemble the galls made by any known insect. Secondly, although insects or remains of insects are generally found in old knots, in most cases no insects at all are found in them when young. Thirdly, the insects that have been found by entomologists in the knots are not all of one species, but of several different species, which are also found on trees which are never affected by the knot. On the other hand, we never have the black knot without the *Sphæria morbosa*, as was admitted by Harris;* and the mycelium of that fungus is found in the slightly swollen stem long before any thing which could be called a knot has made its appearance. Furthermore, the *Sphæria morbosa* is not known to occur anywhere except in connection with the knots.

That the fungus on the cherry and plum is the same, as far as all its microscopic characters are concerned, is certain beyond a doubt. The only reason why there has appeared to be any doubt on this subject is, that some kinds of cherries are susceptible to the knot, and others are not. Those who believe that there are two different fungi which produce the knot, have started with the assumption that what is true of one kind of cherry, as far as susceptibility to disease is concerned, is true of all cherries. Having seen some cherries free from the knot, although growing near diseased plum-trees, and others, perhaps not near any plum-trees, covered with knots, they have jumped at the conclusion, that there must be two different fungi producing the knot: one on the cherry, derived from the wild cherry; another on the plum, derived from the wild plum. Now, we have no right whatever to infer that a disease of fungoid origin will be found on plants closely related botanically. In fact, we have no right to infer any thing; we can only examine and find out what the fact is. Let us see, first, how the case stands with our wild cherries, as the species are well marked, and we know more exactly what we are talking about than when we speak of the confused cultivated varieties. *Prunus serotina*, Ehrhart, the rum cherry, and *Prunus Virginiana*, L., the choke cherry, are about equally common near Boston. The latter is very frequently attacked by the knot; the former never, as far as our experience goes, and we have examined hundreds of trees. Walsh and others also testify to the same effect. The following is a striking illustration: In

* *Vide* quotation on page 449.

the month of March, 1875, we went to a hedge of wild cherries, in search of specimens of the knot, but found them only on one tree, although very abundant on that. When the trees had leaved out, a few weeks later, we passed by the hedge and observed that all the trees but one were *Prunus serotina;* and that one (the same from which we had gathered specimens of the knot) was *P. Virginiana.*

Prunus Pennsylvanica, L., the bird cherry, is subject to the disease; and, also, *Prunus Americana*, Marsh, the wild plum, on the authority of Prof. C. E. Bessey, Walsh, and others. Harris makes the statement that the last-named species is not subject to the knot; but he was probably mistaken, as so many others affirm the contrary. *Prunus maritima*, Wang, the beach plum, as far as our experience in southern Massachusetts goes, is free from the knot. Of *Prunus Chickasa*, Michx., we have no definite information. The single case reported by Walsh of a black knot occurring on a peach-tree is extremely doubtful.

If we turn now to the cultivated varieties of plums and cherries, we also find that some are susceptible to the disease and others are not. Without doubt, the morello cherry is more susceptible than any other variety, and next in order comes the mazzard. Whether any other varieties of cultivated cherries are liable to the knot, we cannot say, speaking from our own experience, and the accounts published in the journals are so indefinite and contradictory that one does not know what to believe. That some varieties are free from the disease, we know to be a fact; for we have very frequently seen orchards of other varieties than the morello and black mazzard entirely free from the knot, although, in some cases, infected choke cherries were actually growing under the cultivated trees, and plum-trees in the neighborhood were badly diseased.

We have little hesitation in asserting, judging from our observations and the more reliable reports in the agricultural journals, that there is no variety of cultivated plum which is not subject to the black knot. To suppose that the disease came from the wild plum, rather than the wild cherry, is quite superfluous; for, in the region of Boston, where the black knot has almost completely destroyed the cultivated plums, the wild plum is very rare, if it occurs at all, and the disease must have come from the choke cherry or the bird cherry. We have made direct experiments to show that the spores of the knot on the choke cherry will germinate and produce the knot in healthy plum-trees, and the results will be given in a future number of the Bulletin.

Prevention of the Disease. — From the knowledge that the knot is a contagious disease, caused by a fungus whose ascospores are ripened in midwinter, and whose mycelium does not extend for more than a few inches below the knots, and bearing in mind that the fungus is indigenous on certain of our native species of Prunus, the remedy is obvious. When a knot makes its appearance, the branch should be cut off a short distance below the slight swelling of the stem, which is found just below the knot. When cut off, the branches should be burnt, to prevent the spores from spreading the disease; for, although the asci may have but begun to form when the branch is cut off, they will grow and ripen their spores even when separated from the trees, as we know from experience.* The question arises as to the best time for cutting off the diseased branches. We should say, cut them off whenever one sees them. The most favorable time is late in the autumn, before the ascospores are ripe. But it must not be forgotten that the conidia ripen in early summer; and, if knots are seen in the spring, they should be cut off at once.

Not only should diseased branches of cultivated cherries and plums be removed; but all means should be taken to destroy the choke cherry, the bird cherry, and the wild plum, in the neighborhood of orchards. In New England, particularly, the choke cherry can only be regarded as a pest. We notice that Mr. Emerson, in the new edition of his "Trees and Shrubs of Massachusetts," recommends the choke cherry as worthy of cultivation on account of its beauty. However opinions may differ as to its beauty, there can be only one as to its injurious influence on cherry and plum orchards; and it cannot be too strongly impressed upon fruit-growers, that the choke cherry is a most dangerous enemy, and should be destroyed. It is quite time that it was generally understood, that many of our herbaceous and shrubby plants cause or, at any rate, increase disease in our vegetables and fruit-trees. The farmer destroys caterpillars wherever and whenever he finds them; why should he not also cut down and destroy all trees and shrubs which carry a contagious disease into his fruit orchards?

* A plum-tree covered with knots was cut down at Newton, Mass., towards the end of the summer of 1875, before the ascospores had begun to form; but by the first of the following March ripe spores were formed in all the knots, notwithstanding the fact that on the first of the previous December the tree had been exposed to a temperature of — 8° F.

In the preceding pages, we have attempted to dispel a certain mystery which hangs about the black knot in the minds of fruit-raisers, and to convince them that it is amenable to treatment. We can hardly expect, seeing how wide-spread the disease is in the eastern part of our country, that it will be entirely driven off, except by extraordinary exertions on the part of fruit-raisers. Knowing, however, where it comes from and how it is propagated, there can be no possible excuse for allowing it to spread to parts of the country which are at present free from the disease. The disease is as yet unknown in Europe, and there is little probability that it will be introduced by the importation of cultivated American varieties of plums or cherries. It is more likely to find its way to Europe on our wild species which may be introduced into the different botanical gardens, and the directors of such gardens should be very cautious about importing *Prunus Virginiana*, *P. Americana*, or *P. Pennsylvanica;* for the black knot would prove an unwelcome guest, in comparison with which the now notorious Babington's curse would seem insignificant.

EXPLANATION OF PLATES.

Plate I.

Fumago salicina, Tul., on olive leaves, magnified 600 diam.

1. Stylospores.
2. Mycelium on scale of leaf.
3. *a*, pycnidia; *c*, conidia.

Plate II.

1. Peronospora viticola, B. and C., conidia magnified 600 diam.
2. Tip of branch more highly magnified.
3. Haustoria in stem of Vitis cordifolia.
4. Conidia of Peronospora nivea, Unger, from leaf of Geranium maculatum.
5. Conidia of Peronospora effusa, Grev., from leaf of Plantago major.
6. Conidial spore germinating.

Plate III.

1. Oöspore of Peronospora effusa, Grev., from leaf of Plantago major, magnified 750 diam.

2. Oöspore of Peronospora viticola, from Vitis æstivalis.

3, 4, 5, 6, 7, 8. Different stages of development of the zoöspores of P. viticola; 8 is drawn on a larger scale than 6 and 7.

Plate IV.

1. Sphæria morbosa, Schw., black knot on cultivated plum. May. Natural size.

2 and 3. Sections of young knot from a choke cherry. Natural size.

Plate V.

1. Sphæria morbosa on cultivated plum. Autumn. Natural size.

2. Section of knot on choke cherry in May, magnified 600 diam. *a*, mycelium; *b*, conidia.

3. Conidia more highly magnified.

4. Section through one side of cavity containing stylospores. From mazzard cherry.

5. Stylospores more highly magnified.

Plate VI.

1. Section of choke cherry stem, showing mycelium before it has come to the surface, magnified 600 diam.

2. Spermagonia.

3. Asci and spores of Sphæria morbosa from choke cherry.

4. Perithecium with asci.

4, 5. Ripe ascospores.

6, 7. Ascospores germinating.

No. 25. — *Report of the Director of the Arnold Arboretum, presented to the President and Fellows of Harvard University.*

To the President of the University: —

Sir, — I have the honor to submit the following Report of the present condition of the Arnold Arboretum, and of its progress during the nine months which have elapsed since the date of my last Report, December 1, 1874: —

The Green-houses of the Bussey Institution having been placed at my disposal for the uses of the Arboretum, they have been devoted to the raising of forest and ornamental trees and shrubs for future plantations. Many of the plants of the last catalogue, which were then represented by only a few specimens, have now been raised in sufficient quantities, and 165 species have been added to the collection. Probably over 100,000 ligneous plants have been raised during the nine months.

The operation of thinning out the old trees with a view to their future improvement has been continued during the year, and the woods in the various portions of the grounds are now in such a condition that their further thinning is not for the present desirable.

Some two acres on the hill-side which forms the south-eastern boundary of the Arboretum, lying directly in the rear of the Stone Building of the Bussey Institution, have been planted with alternate Larch, Spruce, and Box Elder, to supply a needed shelter to the Plainfield from the north-west winds, and to define the boundary of the Arboretum in that direction.

As many as 5,542 trees and shrubs have been presented during the nine months to various establishments and individuals throughout the United States interested in Arboriculture, and 69 have been sent to the Royal Gardens, Kew, England.

The largest recipients have been the new Botanic establishment at Chicago, the Massachusetts Agricultural College at Amherst, and the University of Vermont. The department of propagation of the Botanic Garden has been transferred to the Arboretum, with excellent results in every way. The Green-houses are better suited for such

operations than those at Cambridge, and the whole attention of the assistants being directed to the raising of seedlings, they are enabled to produce plants more surely and with much greater economy.

Of plants so propagated, 1,643 have been placed in the Botanic Garden during the nine months, and 5,520 have been distributed in the name and for the benefit of that establishment.

The many contributions to the Arboretum having, for greater convenience, been mentioned in my Report of the condition of the Botanic Garden, it is unnecessary to acknowledge them here.

C. S. SARGENT, *Director.*

SEPTEMBER, 1875.

APPENDIX A.

A CATALOGUE OF THE LIGNEOUS PLANTS RAISED AT THE ARNOLD ARBORETUM DURING THE NINE MONTHS ENDING SEPTEMBER 1, 1875.

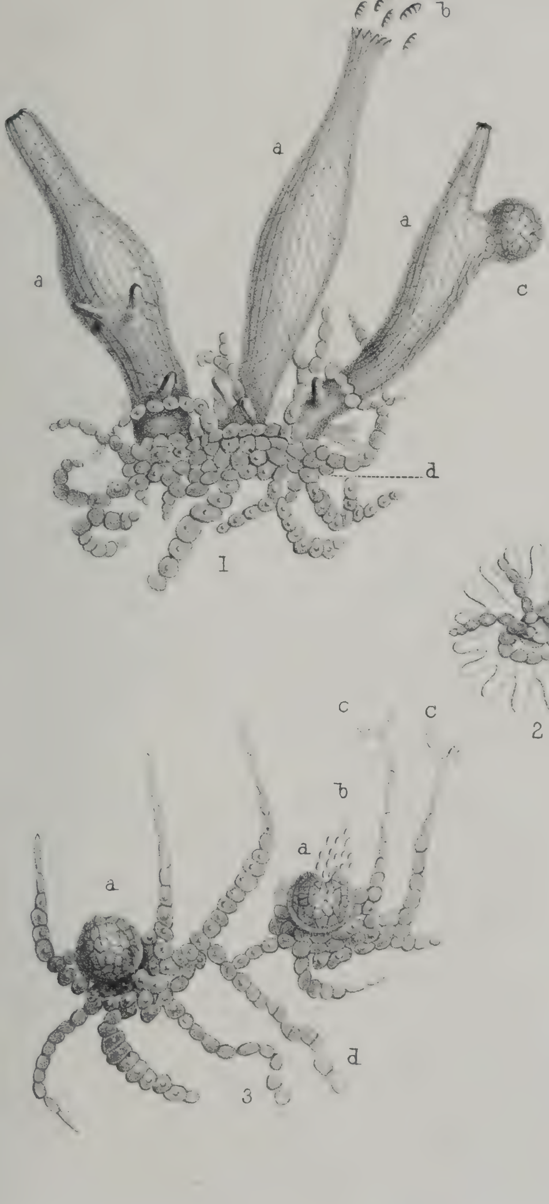
Clematis Fremontii, Watson.
Clematis Vitalba, L.
Clematis alpina, Mill.
Clematis ligusticifolia, Nutt.
Magnolia acuminata, L.
Magnolia conspicua, Salisb.
Maximowiczia Chinensis, Rupr.
Berberis Cretica, L.
Berberis petiolaris, ——— ?
Berberis Fremontii, Torr.
Berberis Aquifolium, Pursh.
Helianthemum vulgare, Gærtn.
Hypericum hircinum, L.
Tilia Europæa, L.
Tilia argentea, DC.
Tilia Americana, L.; *var.* pubescens.
Rhus glabra, L.
Vitis Labrusca, L.
Vitis æstivalis, Mich.
Vitis Californica, Benth.
Rhamnus lanceolatus, Pursh.
Ceanothus velutinus, Dougl.
Ceanothus integerrimus, Hook.&A.
Ceanothus divaricatus, Nutt.
Ceanothus rigidus, Nutt.
Ceanothus prostratus, Benth.
Euonymus occidentalis, Nutt.
Æsculus parviflora, Walt.
Zanthoceras sorbifolia, Bunge.
Acer tartaricum, L.
var. Ginnala, Maxim.
Acer platanoides, L.
Acer oblongum, Walt.
Acer Pennsylvanicum, L.
Acer saccharinum, Wang.
Laburnum vulgare, Griseb ; *var.*
Genista Sibirica, L.
Cytisus supinus, Jacq.
Photinia arbutifolia, Lindl.
Colutea orientalis, Lam.
Maackia Amurensis, Rupr. & Max.
Sophora Japonica, L.
Cercis Siliquastrum, L.
Prunus Chicasa, Mich.
Prunus Pennsylvanica, L.
Prunus Caroliniana, Ait.
Prunus subcordata, Benth.
Prunus Andersonii, Gray.
Prunus Padus, L. ; *var.* parviflora.
Prunus sinensis, Pers. ; *var.* flore pleno, Hort.

Spiræa confusa, Rgl. & Kcke.
var. mollis, Koch.
Spiræa Fortunei, Planch.
Spiræa alba, Duroi.
Spiræa salicifolia, L.
Cercocarpus betuloides, Nutt.
Cercocarpus ledifolius, Nutt.
Purshia tridentata, DC.
Rubus hispidus, L.
Rubus thyrsiflorus, Weihe.
Rubus cratægiflorus, Bunge.
Rosa Alpina, L.
var. glandulosa.
Rosa sericea, Lindl.
Rosa micrantha, Smith.
Rosa rubrifolia, Vill.
Cratægus Oxyacantha, *var.* Sibirica.
Cratægus tomentosa, L.
Cratægus parviflora, Ait.
Cratægus pinnatifida, Bunge.
Photinia arbutifolia, Lindl.
Pyrus Malus, L. ; *var.* hyemalis.
Pyrus baccata, L.
var. genuina.
var. stricta, Rgl.
var. præcox, Rgl.
Pyrus Aria, Ehrh.
Pyrus pinnatifida, Smith.
Pyrus arbutifolia, L.
Pyrus Japonica, Thurb.
Ribes Cynosbati, L.
Ribes irriguum, Dougl.
Ribes prostratum, L'Her.
Ribes cereum, Dougl.
Itea Virginica, L.
Aralia racemosa, L.
Aralia spinosa, L.
Aralia cordata, Thbg.
Cornus sericea, L.
Cornus pubescens, Nutt.
Garrya elliptica, Lindl.
Garrya Fremontii, Torr.
Nyssa capitata, Nutt.
Sambucus racemosa, L.
Sambucus Ebulus, L.
Viburnum acerifolium, L.
Symphoricarpus vulgaris, Mich.
Lonicera Maximowiczii, Rupr.
Lonicera chrysantha, Turcz.
Lonicera Ruprechtiana, Rgl.
Lonicera alpigena, L.
Lonicera Xylosteum, L. *var.* mollis.
Erica vagans, L.
var. alba, Bree.
Arbutus Menziesii, Smith.
Arctostaphylos pungens, H. B. K.
Andromeda speciosa, Michx.
Andromeda Mariana, L.
Rhododendron Caucasicum, Pall, *var.* luteum.
Rhododendron hirsutum, L.
Rhododendron parvifolium, Adams.
Azalea pontica, L.; *var.* imperialis.
Azalea pontica, L.; *var.* princeps.
Azalea occidentalis, Torr.
Rhodora Canadensis, L.
Clethra acuminata, Mich.
Clethra alnifolia, L.
Ilex opaca, Ait.
Ilex coriacea, Chapm.
Diospyros Virginiana, L.
Tecoma radicans, Juss.
Forsythia viridissima, Lindl.
Syringa vulgaris, L.
Ligustrum vulgare, L. ; *var.* chlorocarpum.
Ligustrum Japonicum, Thunb.
Fraxinus pubescens, Lam.
Fraxinus anomala, Torr.
Elægnus parviflora, Walt.
Morus multicaulis, Perr.
Juglans nigra, L.
Carya sulcata, Nutt.
Quercus Cerris, L.
Quercus obtusiloba, Mich.
Quercus nigra, L.
Quercus Catesbæi, Mich.
Quercus myrtifolia, Wildn.
Quercus undulata, Torr.
Quercus sinuata, Walt.
Quercus aquatica, Catesb.
Fagus ferruginea, Ait.

Fagus sylvatica, L.
Carpinus Duinensis, Scop.
Betula alba, L.
Salix, *species*.
Araucaria imbricata, Don.
Pinus contorta, Dougl. ; *var.* latifolia, Engelm.
Pinus Banksiana, Lamb.
Pinus Pinea, L.
Pinus Halepensis, Mill.
Pinus sylvestris, L.
Pinus Austriaca, Host.
Pinus Khasyana, Hook. fil.
Pinus Coulteri, Don.
Pinus tuberculata, Don.
Pinus Cembra, L.
Pinus flexilis, James.
Abies Menziesii, Dougl.
Abies Fraseri, Pursh.
Abies obovata, Loudon.
Larix Europæa, DC. ; *var.* Rossica, Endlicher.
Actinostrobus pyramidalis, Miq.
Cupressus thyoides, L.
Biota orientalis, Endlicher ; *var.* Nepalensis, Hort.
Smilax Walteri, Pursh.
Smilax glauca, Nutt.

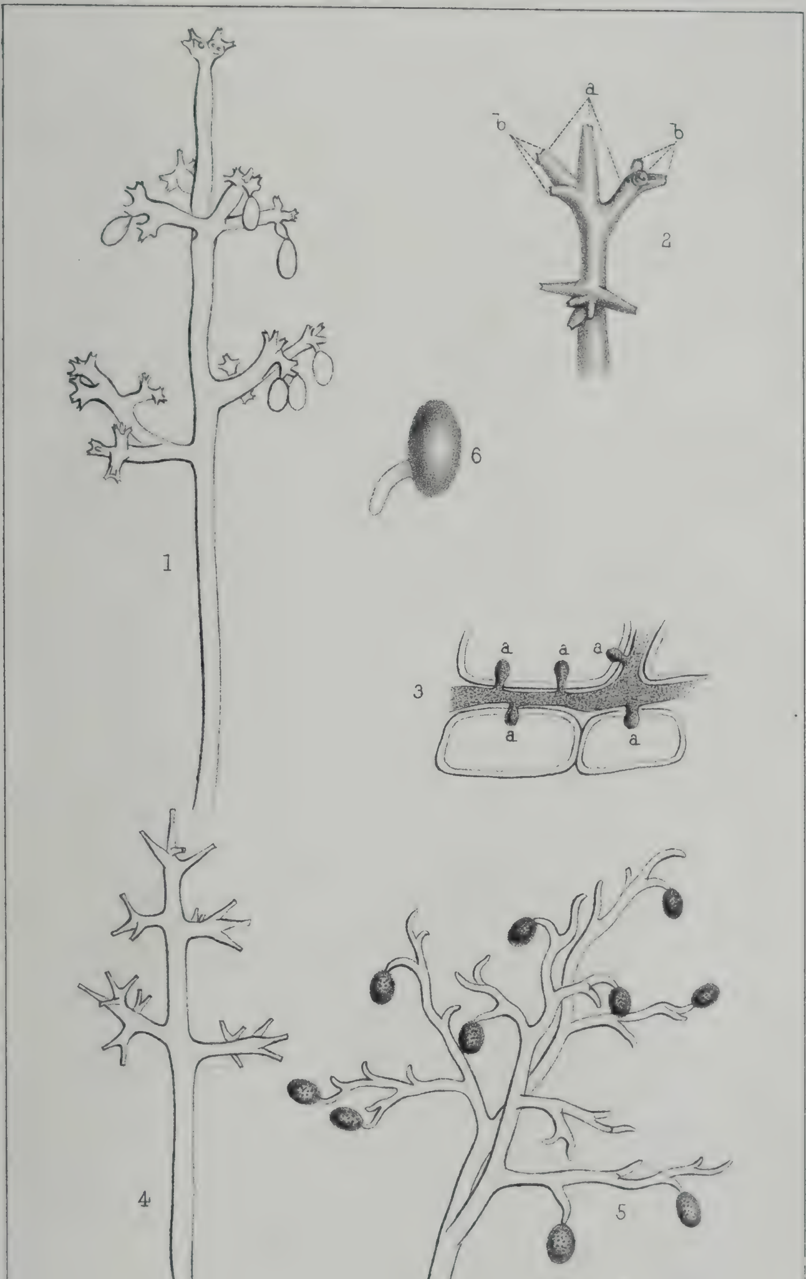
INDEX.

Cambridge: Press of John Wilson & Son.

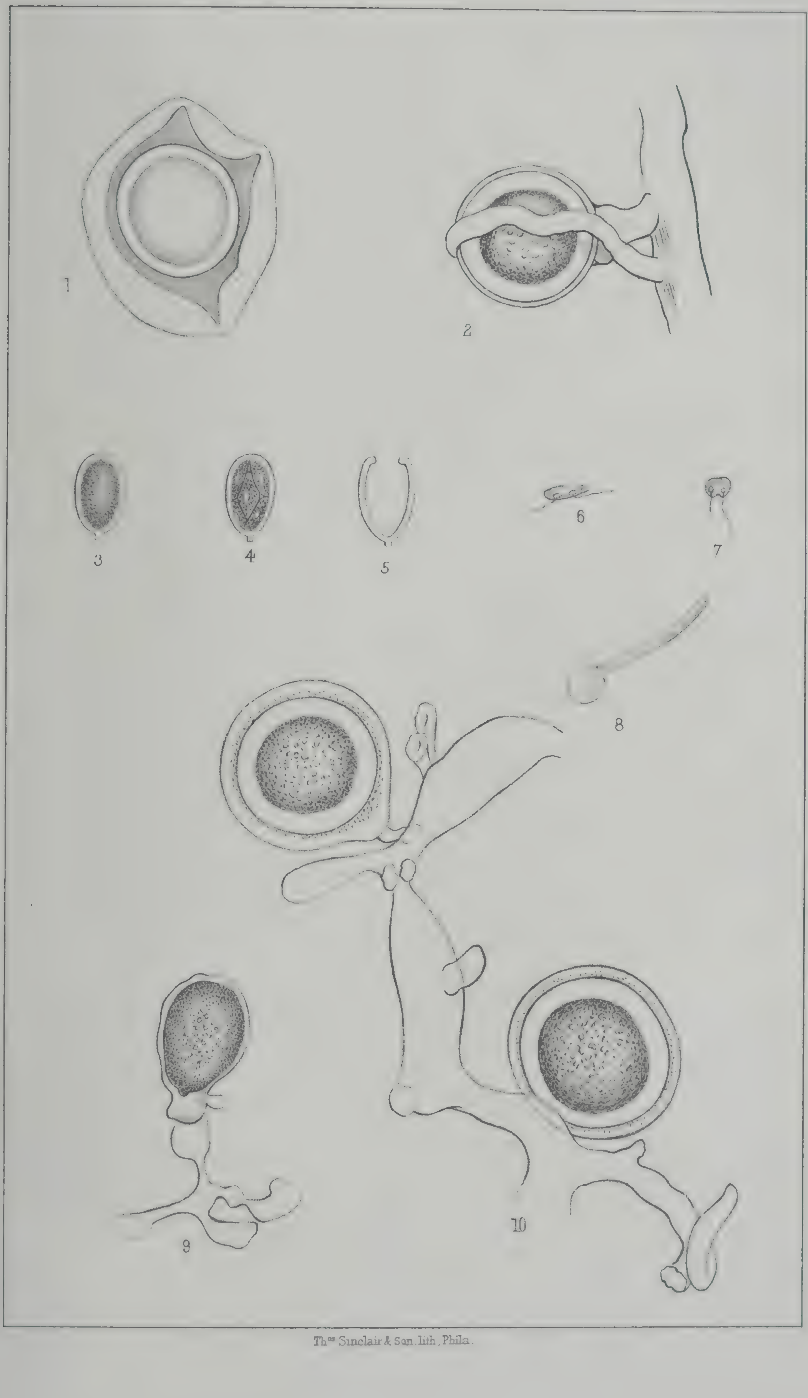


T. Sinclair & son, lith. Phila

PLATE II.



T Sinclair & Son, lith. Phila.

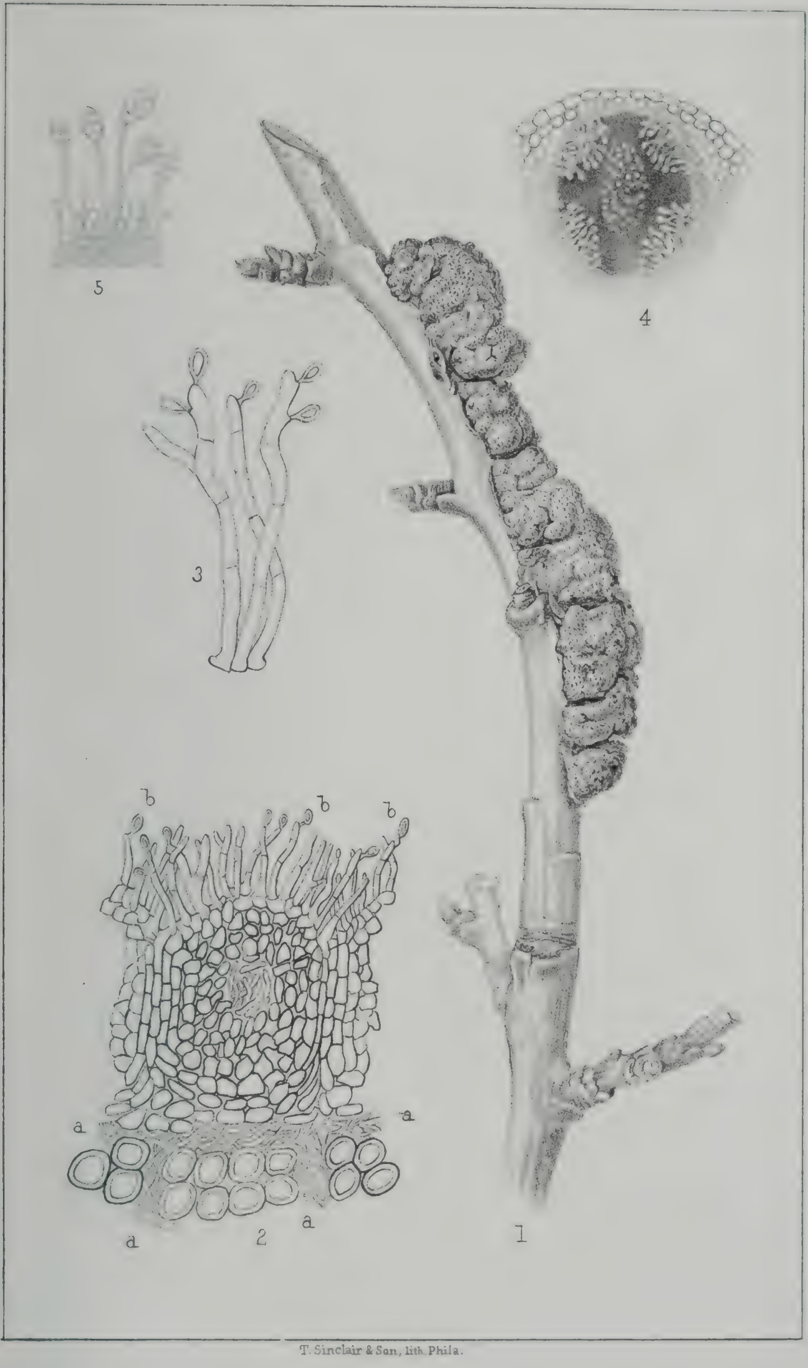


Thos Sinclair & Son, lith. Phila.

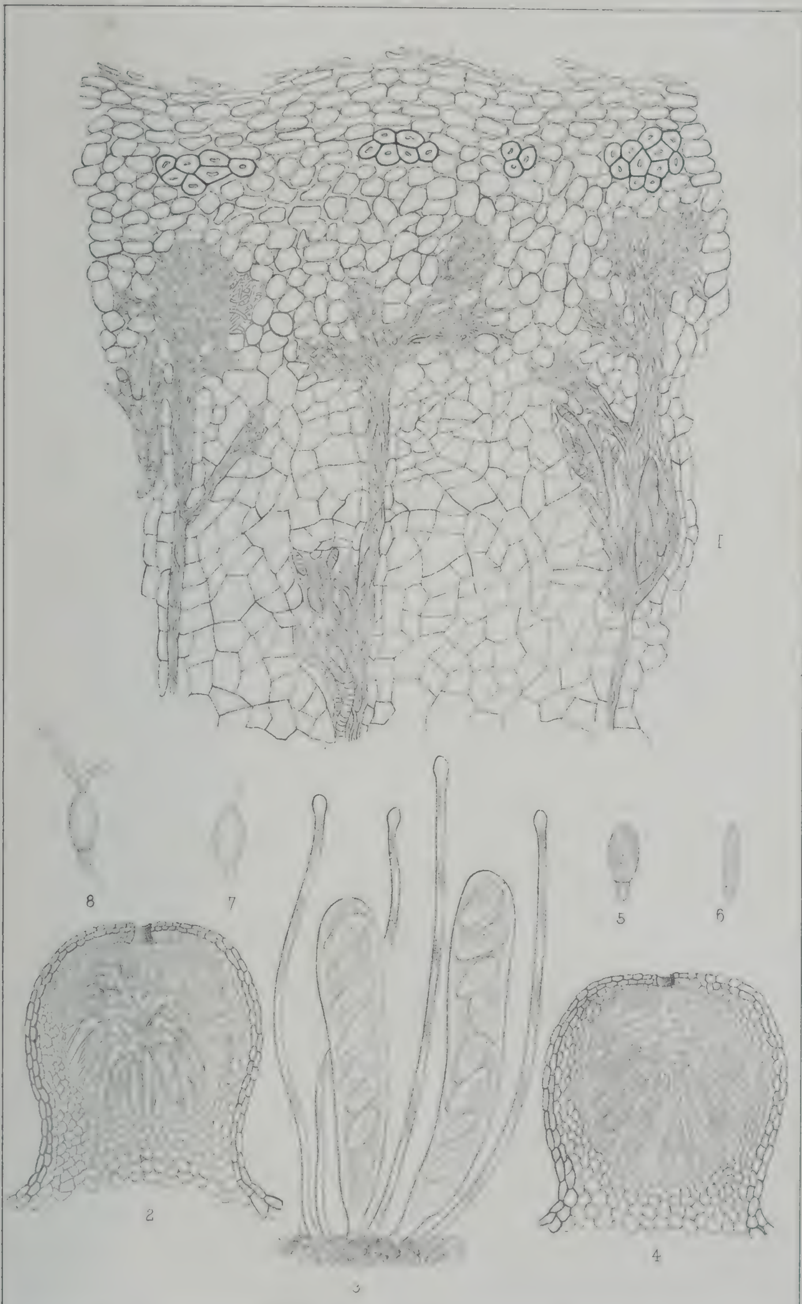
PLATE IV.

T. Sinclair & Son. lith. Phila.

PLATE V



T. Sinclair & Son, lith. Phila.



Thos Sinclair & Son, lith, Phila.